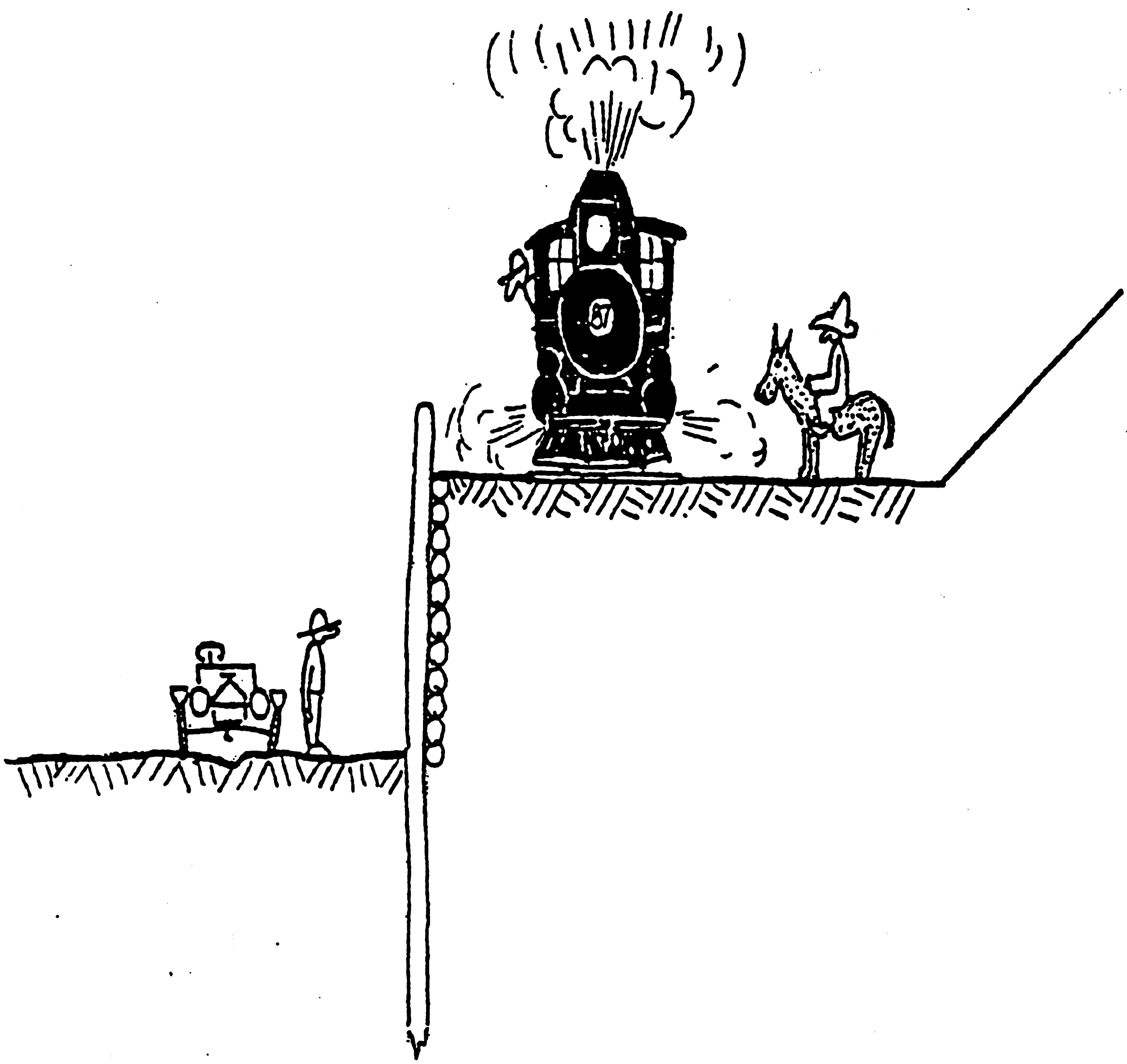
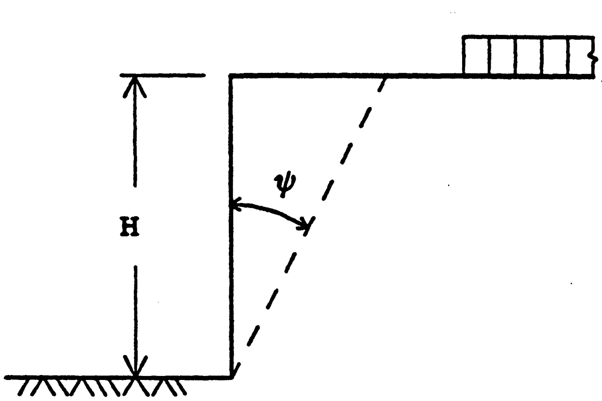
SURCHARGES



SURCHARGE LOADS

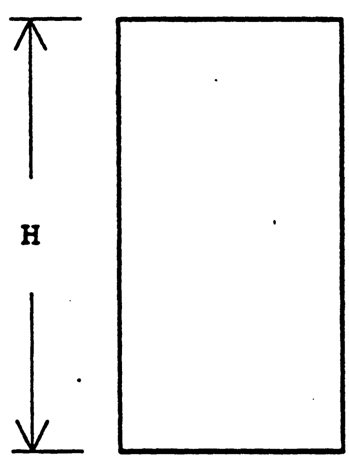
A surcharge load is any load which is imposed upon the surface of the soil close enough to the excavation to cause a lateral pressure to act on the system in addition to the basic earth pressure. Groundwater will also cause an additional pressure, but it is not a surcharge load.

Examples of surcharge loads are spoil embankments adjacent to the trench, streets or highways, construction machinery or material stockpiles, adjacent buildings or structures, and railroads.



A soil surcharge load 4' or less in height will not need to be considered if the load is positioned to the right of the assumed* failure plane as shown. With higher, irregular, or sloping embankments it will be necessary to consider all loads acting on wedges used in the Trial Wedge analysis.

MINIMUM CONSTRUCTION SURCHARGE



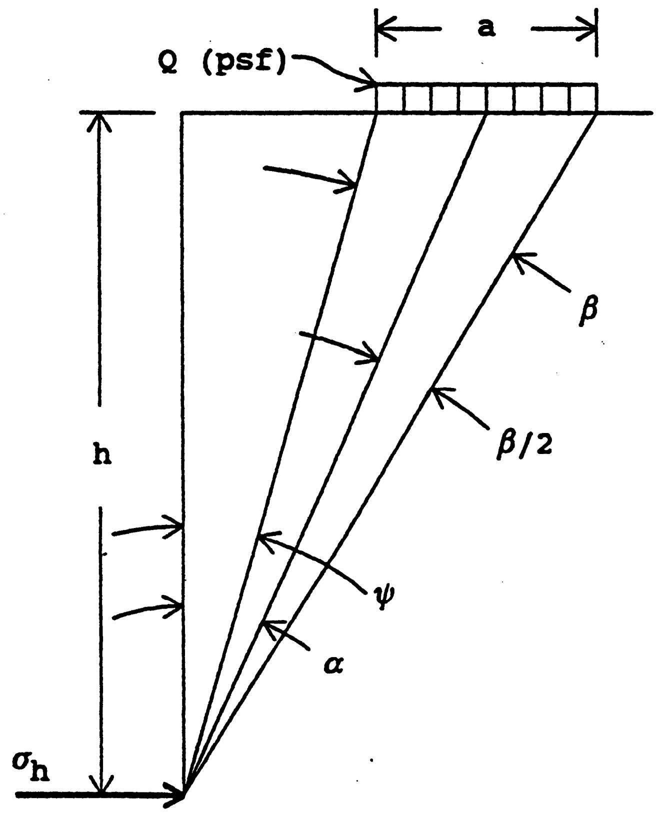
This surcharge load results in a uniform lateral pressure of 72 psf. It shall be used when making an engineering analysis of all types of shoring systems. This surcharge is intended to provide for the normal construction loads imposed by small vehicles, equipment, or materials, and workmen on the area adjacent to the trench or excavation. It should be added to all basic earth pressure diagrams. Thisminimum surcharge can be compared to a soil having parameters of γ = 109 pcf and K_a = 0.33 for a depth of 2 feet [(0.33)(109)(2) = 72 psf]

Surcharge loads which produce lateral pressures greater than 72 psf would be used in lieu of the prescribed minimum.

SURFACE LOADS

Any number of surcharge loads can be added to the soil pressure diagram as long as they are analyzed by a proper and proven method. The Boussinesq Strip is one such method and can be used for all surface surcharge loads (unless the load is treated as a soil embankment).

Boussinesq Strip Method: $\sigma_h = 2Q[\beta_R - (\sin\beta)(\cos 2\alpha)]/\pi$



a = width of surcharge strip

σ_h is the intensity of lateral pressure at distance h below top of the excavation (psf). β_R is in radians.

$$\beta_R = \beta(\pi/180)$$

Q is the surface load (psf).

Note: When the surface load starts at the edge of the excavation:

$$\beta = 2\alpha$$

Pay attention to signs; cosines of angles greater than 90° are negative.

In absence of soil data, the soil failure plane angle (ψ) may be assumed as 35° for level surface conditions only.

There are formulas for line and point load surcharges. See the USS Steel Sheet Piling Design Manual. The strip formula can be used satisfactorily for most situations.

BOUSSINESQ STRIP FORMULA

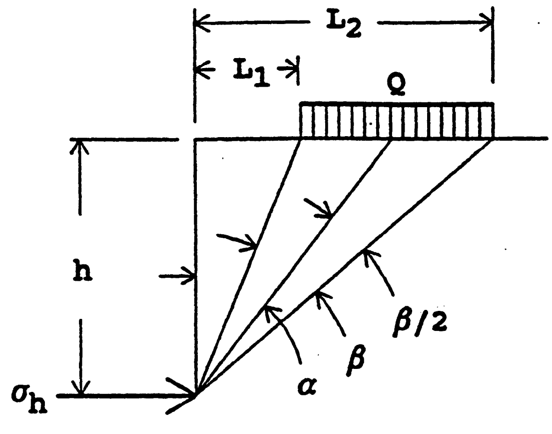


FIGURE 18

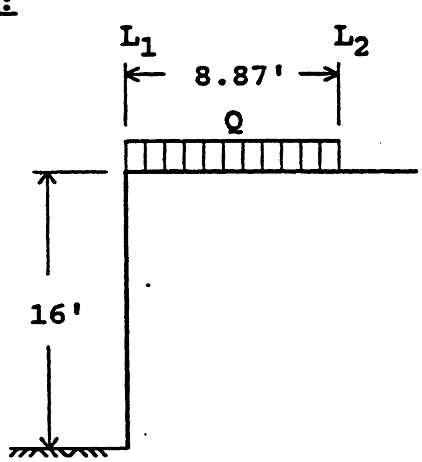
$$\sigma_h = [2Q/\pi][\beta_R - (\sin\beta)(\cos 2\alpha)]$$

When $L_1 = 0$, $\beta = 2\alpha$

Two calculator programs and an extensive table are available at the end of this section for determining lateral pressures due to surcharge.

SAMPLE PROBLEM NO. 4 - BOUSSINESQ STRIP METHOD

GIVEN:



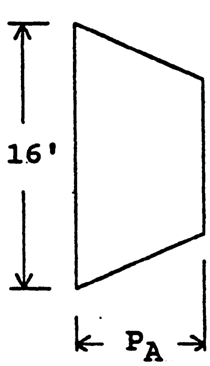
$K_w = 35$ pcf

$Q = 840$ psf

$L_1 = 0$

$L_2 = a = 8.87'$

BASIC SOIL PRESSURE:



Assume for this example that the system is a strutted trench.

$P_A = 0.8K_wH = (0.8)(35)(16) = 448$ psf

SURCHARE PRESSURES:

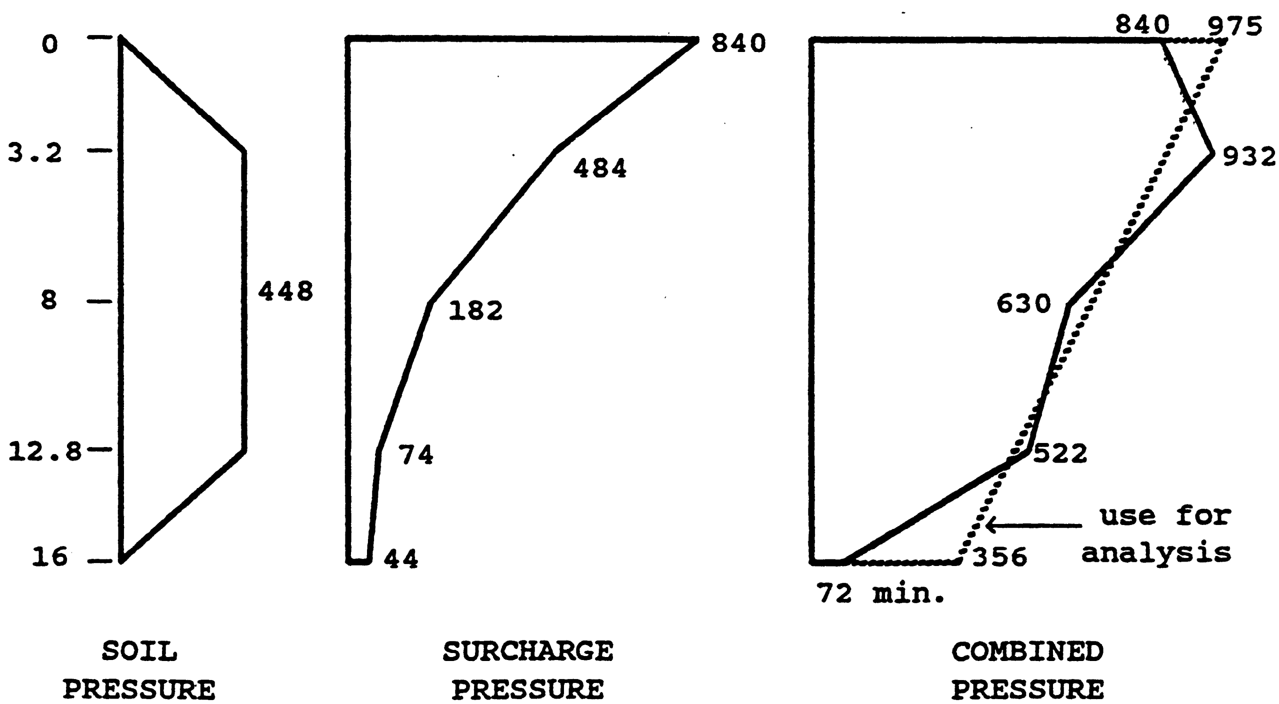
$\sigma_{3.2}$ arctan(8.87/3.2) = 70.16° = 1.224 Radians = β_R
sin β = 0.941 cos 2α = cos β = 0.339
$\sigma_{3.2}$ = [(2)(840)/π][1.224 - (0.941)(0.339)] = 484 psf

σ_8 arctan(8.87/8) = 47.95° = 0.837 Radians = β_R
sin β = 0.743 cos 2α = cos β = 0.670
σ_8 = [(2)(840)/π][0.837 - (0.743)(0.670)] = 182 psf

$\sigma_{12.8}$ arctan(8.87/12.8) = 34.72° = 0.606 Radians = β_R
sin β = 0.570 cos 2α = cos β = 0.822
$\sigma_{12.8}$ = [(2)(840)/π][0.606 - (0.570)(0.822)] = 74 psf

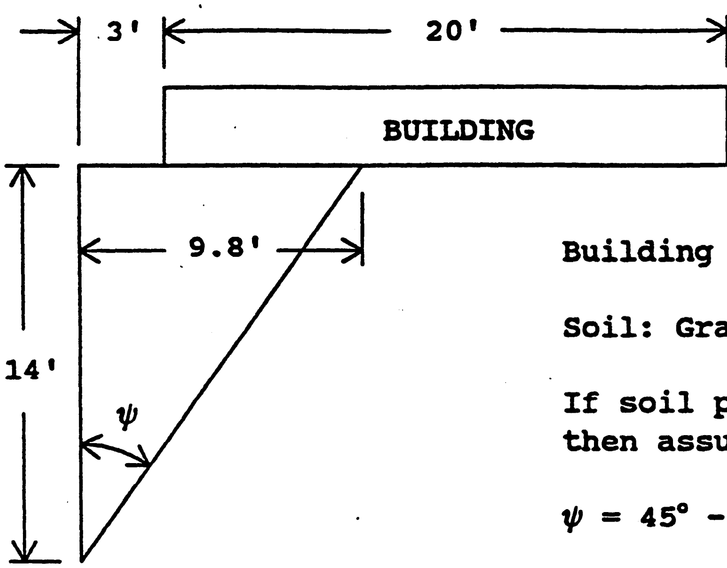
σ_{16} arctan(8.87/16) = 29.00° = 0.506 Radians = β_R
sin β = 0.485 cos 2α = cos β = 0.875
σ_{16} = [(2)(840)/π][0.506 - (0.485)(0.875)] = 44 psf

SUMMARY OF LATERAL PRESSURES:



This method gives consistent and acceptable results. Other surcharge loads may then be added (Q_2, Q_3,....) to the combined diagram to use for design or analysis as was done above.

SAMPLE PROBLEM NO. 5 - BOUSSINESQ STRIP LOAD (FAILURE WEDGE)



Building surcharge Q = 800 psf

Soil: Gravel/sand mix

If soil parameters are not given then assume $\phi = 20°$, $\gamma = 115$ pcf

$\psi = 45° - 20°/2 = 35°$

(14)(tan 35°) = 9.8'

DETERMINE BOUSSINESQ STRIP LOAD pressures for 2 conditions:*

1.) Limit surcharge to failure wedge width (9.8').

2.) Compute value for full width of building surcharge load.

Depth to pressure plane (feet)	Pressure for condition 1 (psf)	Pressure for condition 2 (psf)
0.1	24 < 72	30 < 72
1.0	213	272
2.0	332	446
4.0	341	543
6.0	261	513
8.0	187	456
10.0	132	397
12.0	94	341
14.0	69 < 72	292

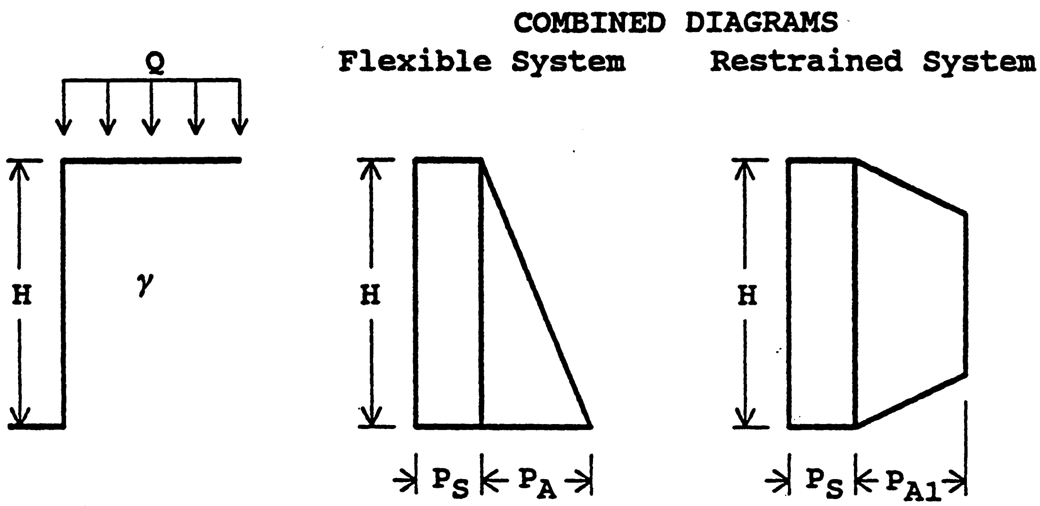
CONDITION 2 CONTROLS

Building, Highway and similar surcharge loadings cannot be limited to the width of the soil failure wedge.

*Note: Soil pressures would be the same for both conditions.

UNIFORM SURCHARGE

A very-wide uniform-load causes an equal&crease in pressure at all depths. This is represented by a rectangular pressure diagram.



$P_S = K_aQ$
$P_A = K_a\gamma H$

Note that the K_a value for the level surcharge will be the same as for the basic soil.

For the restrained system shown above:
$P_{A1} = 0.8P_A$

SAMPLE PROBLEM NO. 6 - UNIFORM SURCHARGE

GIVEN: Restrained system
Depth of trench (H) = 12'
Soil unit weight (γ_1) = 110 pcf
$K_a = 0.36$

Surcharge load consists of a uniform stockpile of materials which weigh 195 pcf, and the stockpile height is 4 feet.

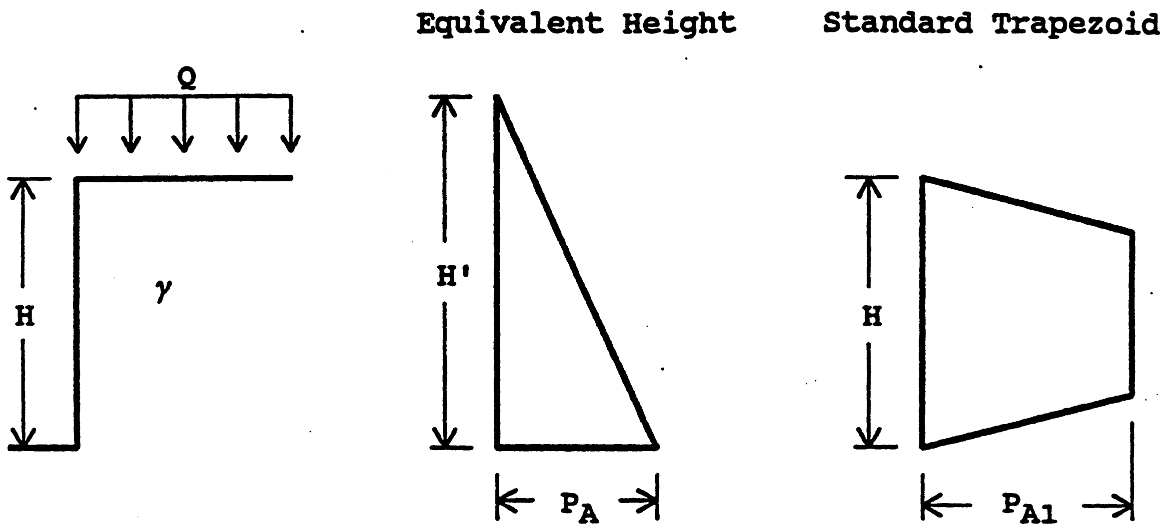
SOLUTION: γ_2 = 195 pcf Q = (195)(4) = 780 psf

$P_S = K_aQ = (0.36)(780)$ = 281 psf > 72 min
$P_A = (0.36)(110)(12)$ = 475 psf

Convert to trapezoid pressure diagram: $P_{A1} = (0.8)(475) = 380$ psf.

UNIFORM SURCHARGE - EQUIVALENT HEIGHT

A uniform load can also be represented by an equivalent height of soil. The height of the original excavation is increased by an amount equal to the surcharge pressure divided by the density of the soil.



SAMPLE PROBLEM NO. 7 - EQUIVALENT HEIGHT

GIVEN: (same as previous example)

$H = 12'$
$\gamma = 110$ pcf
$K_a = 0.36$

SOLUTION: $H_S = Q/\gamma = 780/110 = 7.1'$
$H' = H + H_S = 12 + 7.1 = 19.1'$
$P_A = K_a \gamma H' = (0.36)(110)(19.1) = 756$ psf

Convert to trapezoid distribution:

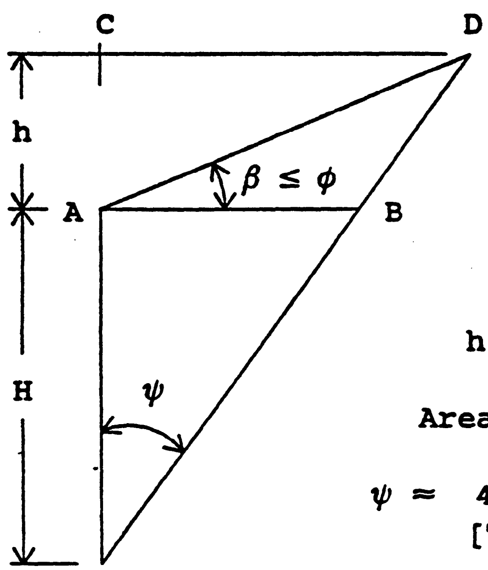
$P_{A1} = (0.8)(756) = 605$ psf

EMBANKMENT SURCHARGE

A recurring shoring problem involves embankments, spoil piles, or surcharge loads adjacent to the excavations which must be considered in the shoring design.

SLOPING EMBANKMENTS:

Conventional analysis (Rankine, Coulomb, or Log-Spiral) should be used for slopes with angles equal to or less than the soil internal friction angle(ϕ)



$$AB = H\tan\psi$$

$$CD = (H + h)\tan\psi$$

$$h = CD\tan\beta$$

$$(H + h)\tan\psi = h/\tan\beta$$

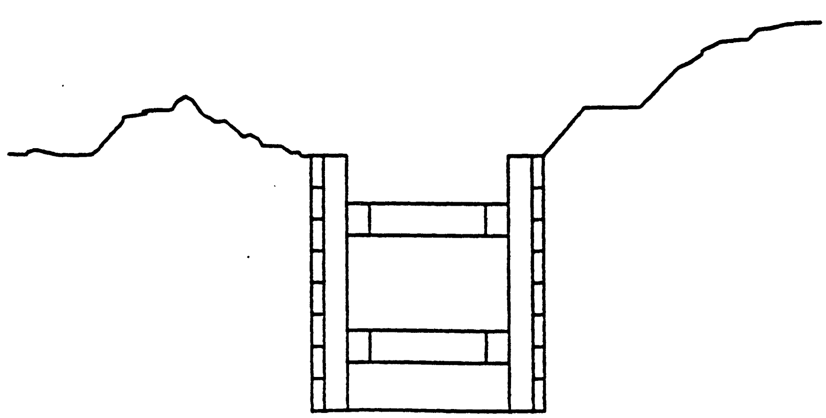
$$h/H = (\tan\psi)(\tan\beta)/\{1 - (\tan\psi)(\tan\beta)\}$$

$$\text{Area } ABD = (h)(AB)/2$$

$\psi \approx 45° - \phi/2$ (or $\approx 35°$ if ϕ not known) [Theoretically for level surfaces only!]

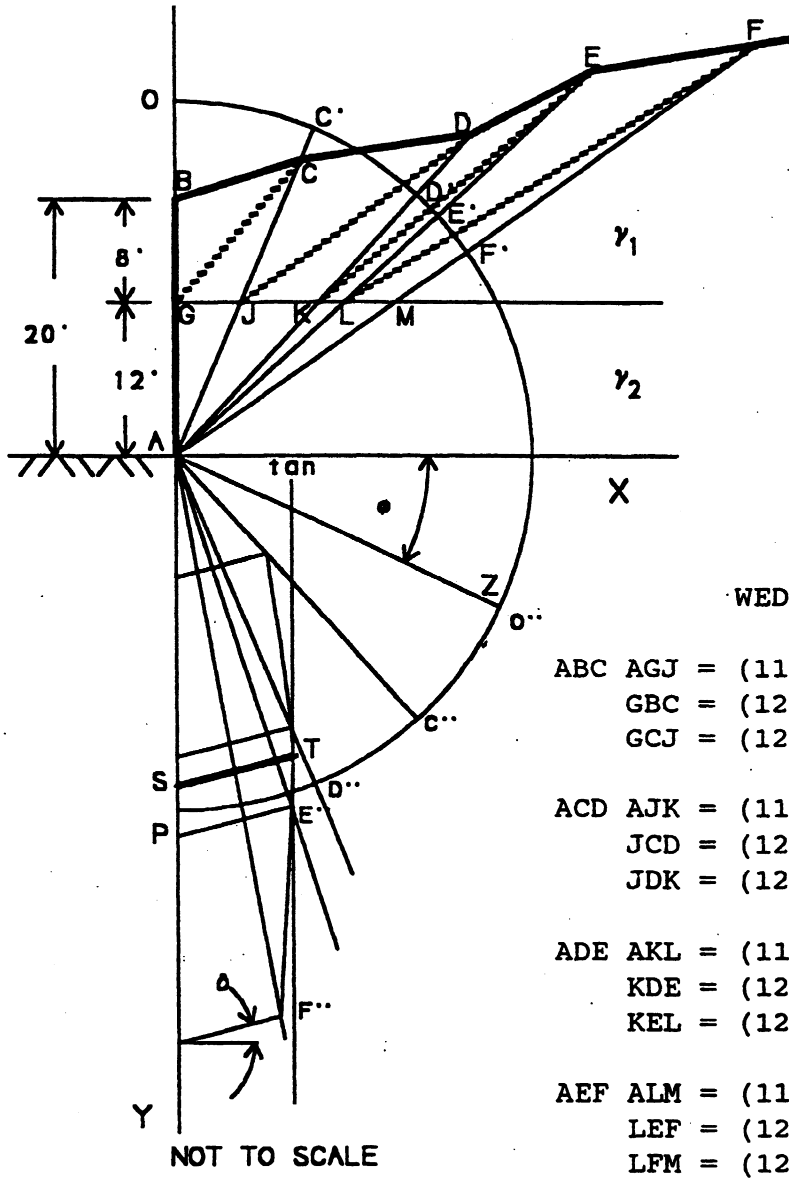
IRREGULAR EMBANKMENTS:

Irregular embankment slopes cannot rationally be converted to the conventional slope analysis method depicted above. Irregular embankment sloping conditions should be analyzed by the Trial Wedge method.



TRIAL WEDGE

The trial Wedge Method is semi-graphical. It is applicable to irregular slopes and varying soil strata.



Known:

ϕ = 25°
γ_1 = 120 pcf
γ_2 = 110 pcf
H = 20'
δ = 15°
C = 0

WEDGE WEIGHT CALCULATIONS:

ABC	AGJ =	(110)(5.0)(12.0)/2 =	3,300
	GBC =	(120)(5.3)(14.6)/2 =	4,643
	GCJ =	(120)(3.8)(14.6)/2 =	3,329
			11,272
ACD	AJK =	(110)(6.0)(12.0)/2 =	3,960
	JCD =	(120)(6.2)(22.1)/2 =	8,221
	JDK =	(120)(3.5)(22.1)/2 =	4,641
			16,822
ADE	AKL =	(110)(2.0)(12.0)/2 =	1,320
	KDE =	(120)(2.3)(27.9)/2 =	3,850
	KEL =	(120)(1.3)(27.9)/2 =	2,176
			7,346
AEF	ALM =	(110)(4.0)(12.0)/2 =	2,640
	LEF =	(120)(5.0)(37.9)/2 =	11,370
	LFM =	(120)(2.1)(37.9)/2 =	4,775
			18,785
		TOTAL:	54,225

ST = P (Total resultant force on system): scales = 11,000 Lb
P_H (Horizontal component) = (11,000)(cos 15^o) = 10,625 Lb

PROCEDURE FOR TRIAL WEDGE SOLUTION

1. Plot wall and soil profile (ABCDEF).

2. Draw AX perpendicular to back of the wall or system.

3. Draw AY vertical.

4. Draw an arc from AO to AP (any convenient radius).

5. Draw rays through break points arid any selected intermediate points (AB, AC, etc) to intersect arc drawn in 4.

6. Compute the individual wedge weights (sea previous sheet).

7. Plot, at a convenient scale, the accumulative wedge weights on AY, down from A (Lb),

8. Draw AZ at angle ϕ, from AX.

9. From AZ, draw rays duplicating those drawn in 5 (AB, AC, etc). The arc distances from AO to each ray is equal to the arc distances from AZ to each duplicate ray.

10. Draw lines at an angle equal to 6 from the wedge weight points along AY to their respective rays drawn in 9.

11. Plot a curve intersecting the points from 10.

12. Establish a point of tangency "T" (with a line parallel to line AY) to that portion or the curve furthermost from line AY.

13. Establish point "S" by sketching a line from point "T", parallel to the lines delineated in step 10. Measure between points S and T, using the same scale used to plot wedge weights, to get the resultant force acting on the shoring at the angle 6.

14. To resolve ST to it's horizontal component (P_H), multiply ST by the cos δ. The total resultant force may be depicted as a force arrow acting on a pressure triangle at 1/3 the height of the vertical excavation. P_A then equals $2P_H/H$.

15. Resolve to the appropriate pressure diagram, which will be dependent upon soil and system type.

COMPARISON OF TEE VARIOUS METHODS USED IN DETERMINING LATERAL SOIL PRESSURES

The following example problems demonstrate differences in methods used to compute soil pressure. The same shoring configuration and the maximum embankment slope angle β (β=ϕ) allowed for in the Coulomb, Rankine, and Log-Spiral methods is used in all cases.

A summary of results follows the example problems.

BASIC CRITERIA FOR ALL PROBLEMS:

$\beta = \phi = 34°$
Friction angle $\delta = 0$
H = 14'
γ = 130 pcf
Assume cantilever system
Wall angle, $\omega = 0$

METHODS TO BE ANALYZED:

Rankine
Coulomb
Log-Spiral
Trial Wedge

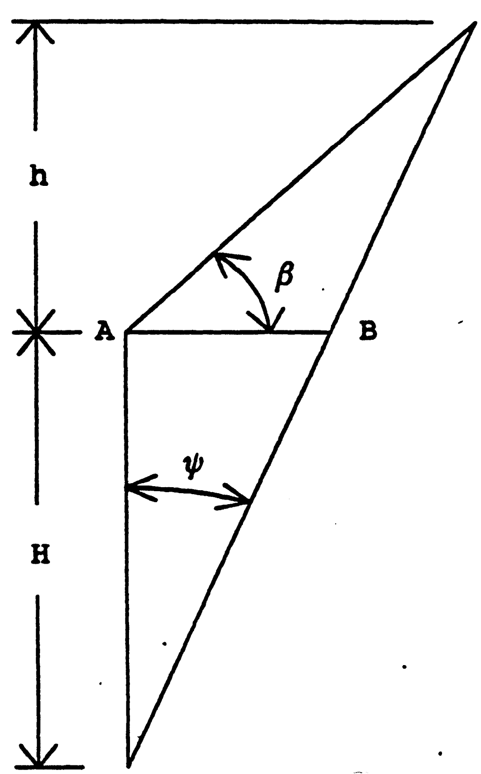
Use approximation for the angle ψ.

$\psi \approx 45° - \phi/2$
$\approx 45° - 17° \approx 28°$

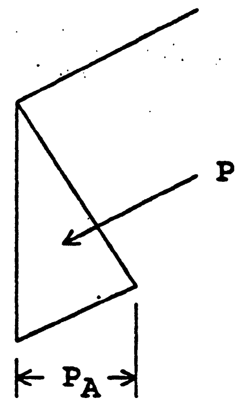
AB = 14(tan 28°) = 7.44'

(14 + h)(tan 28°) = h/(tan 34°)

$\therefore$ h = 7.83'



RANKINE



$$K_a = \cos\beta \cdot \left[\frac{\cos\beta - [\cos^2\beta - \cos^2\phi]^{1/2}}{\cos\beta + [\cos^2\beta - \cos^2\phi]^{1/2}}\right]$$

$$= \cos\beta[1.0] = 0.82904$$

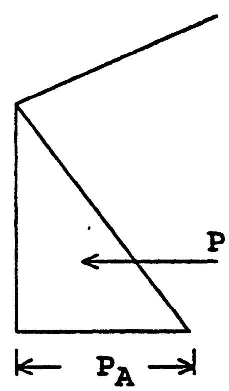
$P_A = K_a\gamma H(\cos\beta) = (0.82904)(130)(14)(\cos 34°)$
$= 1251$ psf

Total Lateral Pressure (P) $= K_a\gamma H^2/2$
$= (0.82904)(130)(14)^2/2 =$ <u>10,562 Lb</u>
(acting at angle β from the horizontal)

COULOMB

$$K_a = \frac{\cos^2\phi}{\cos\delta\left[1 + \sqrt{\dfrac{(\sin(\phi + \delta))(\sin(\phi - \beta))}{(\cos\delta)(\cos\beta)}}\right]^2}$$

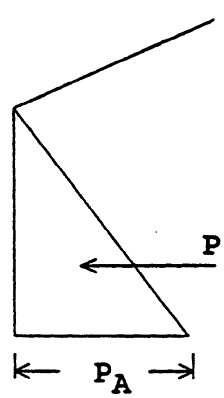
$$= \cos^2\phi[1.0] = 0.6873$$



$P_A = K_a\gamma H = (0.6873)(130)(14)$
$= 1251$ psf

Total Lateral Pressure (P) $= K_a\gamma H^2/2$
$= (0.6873)(130)(14)^2/2 =$ <u>8,756 Lb</u>
(acting at angle δ from the horizontal)

LOG-SPIRAL

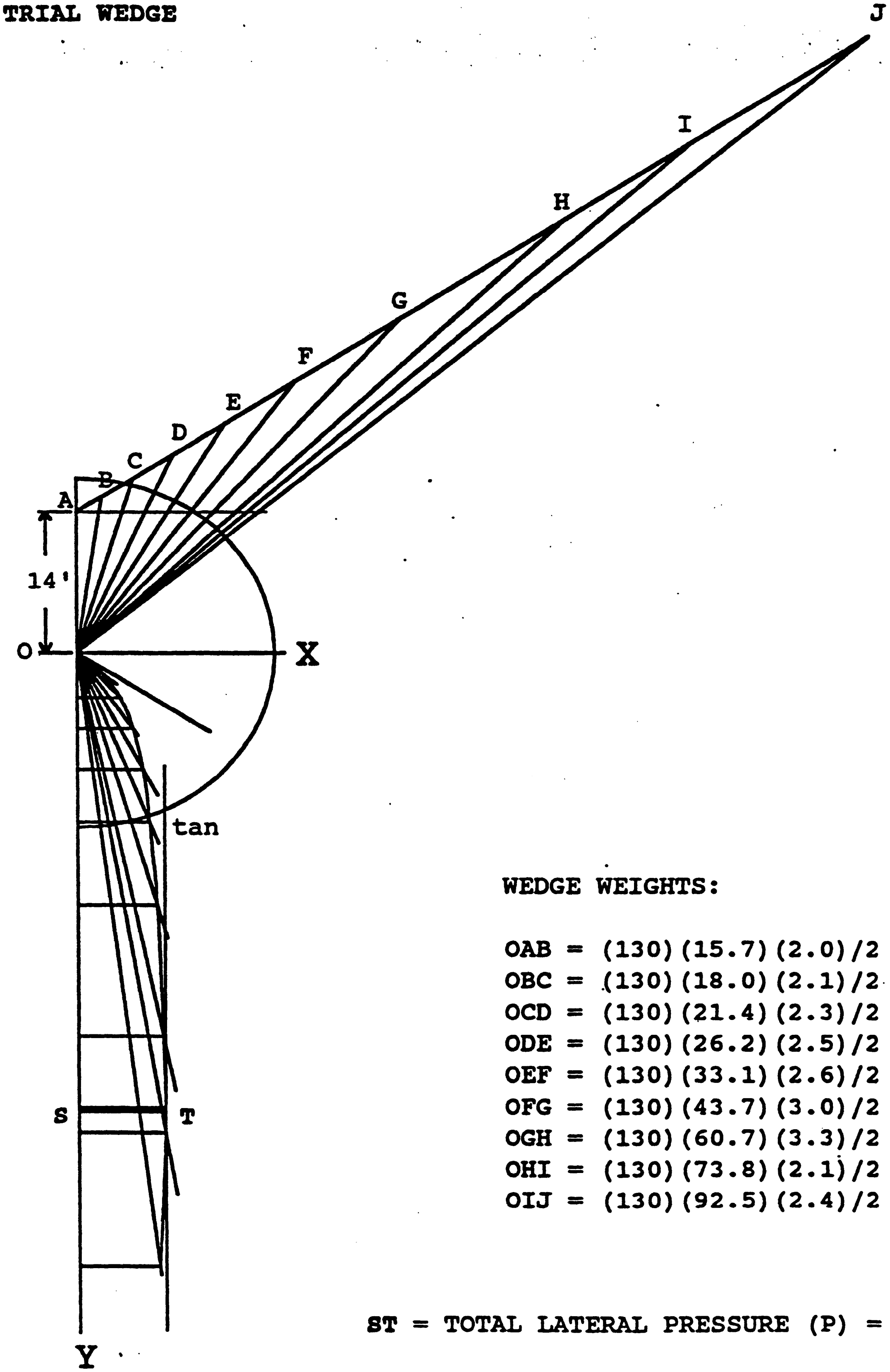


Select K_a from **FIGURE 8**
For $\beta/\phi = 1.0$ and $\delta = 0$ $\quad K_a = 0.78$

$P_A = K_a\gamma H = (0.78)(130)(14) = 1,420$ psf

Total Lateral Pressure (P) $= K_a\gamma H^2/2$
$= (0.78)(130)(14)^2/2 =$ <u>9,937 Lb</u>
(acting at angle δ from the horizontal)

TRIAL WEDGE



WEDGE WEIGHTS:

OAB =	(130)(15.7)(2.0)/2 =	2,041
OBC =	(130)(18.0)(2.1)/2 =	2,457
OCD =	(130)(21.4)(2.3)/2 =	3,199
ODE =	(130)(26.2)(2.5)/2 =	4,258
OEF =	(130)(33.1)(2.6)/2 =	5,594
OFG =	(130)(43.7)(3.0)/2 =	8,522
OGH =	(130)(60.7)(3.3)/2 =	13,020
OHI =	(130)(73.8)(2.1)/2 =	10,074
OIJ =	(130)(92.5)(2.4)/2 =	14,430

ST = TOTAL LATERAL PRESSURE (P) = <u>8,000 Lb</u>

(acting at angle δ from the horizontal)

SUMMARY OF RESULTS - UNIFORM SLOPING EMBANKMENT

Method	Total Lateral Pressure (Lb)*	Horizontal Pressure (Lb)*
Rankine	10,562	8,756
Coulomb	8,756	8,756
Log-Spiral	9,937	9,937
Trial Wedge	8,000	8,000

* Minimum construction surcharge of 72 psf is not included

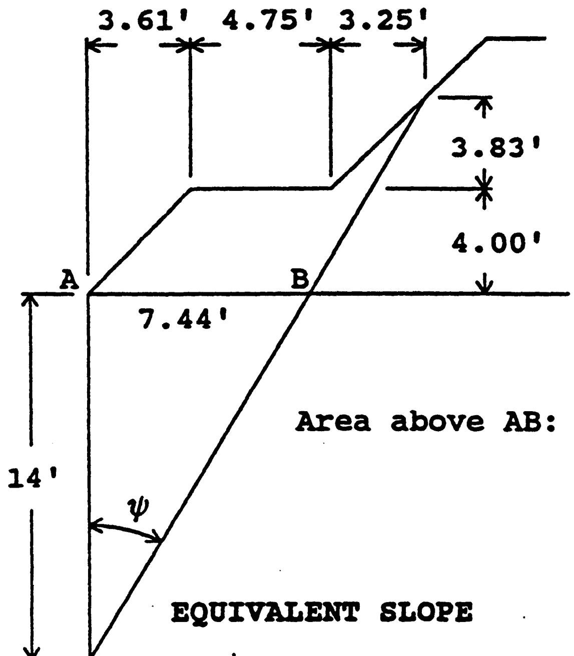
Theoretically the wedge analysis should give the same answer as the Coulomb Method provided $\beta < \phi$, C = 0, and δ = 0.

NOTE: The Log-Spiral method is considered to be the most theoretically correct.

IRREGULAR SLOPED SURCHARGE

As previously stated, the only rational solution for treating irregular sloped embankments is by the Trial Wedge method. Othermeans have been employed, but as the following pages show they are incorrect and should be avoided.

EXAMPLE 11:

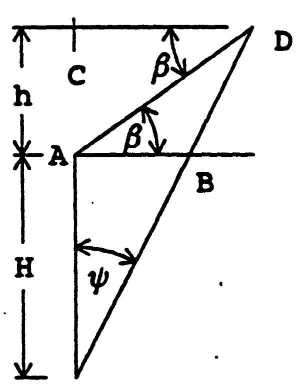


ϕ = 34°
γ = 130 pcf
δ = 0
C = 0
$\psi \approx \tan(45° - \phi/2) \approx 28°$

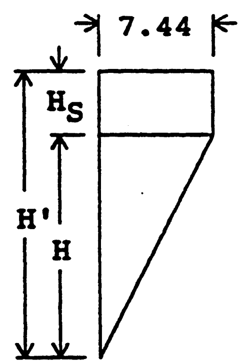
AB = (14)(tan 28°) = 7.44'

Area above AB: (11.61 + 8)(4)/2 + (3.25)(3.83)/2
− (11.61 − 7.44)(7.83)/2
= 29.1 Ft^2/LF

EQUIVALENT SLOPE



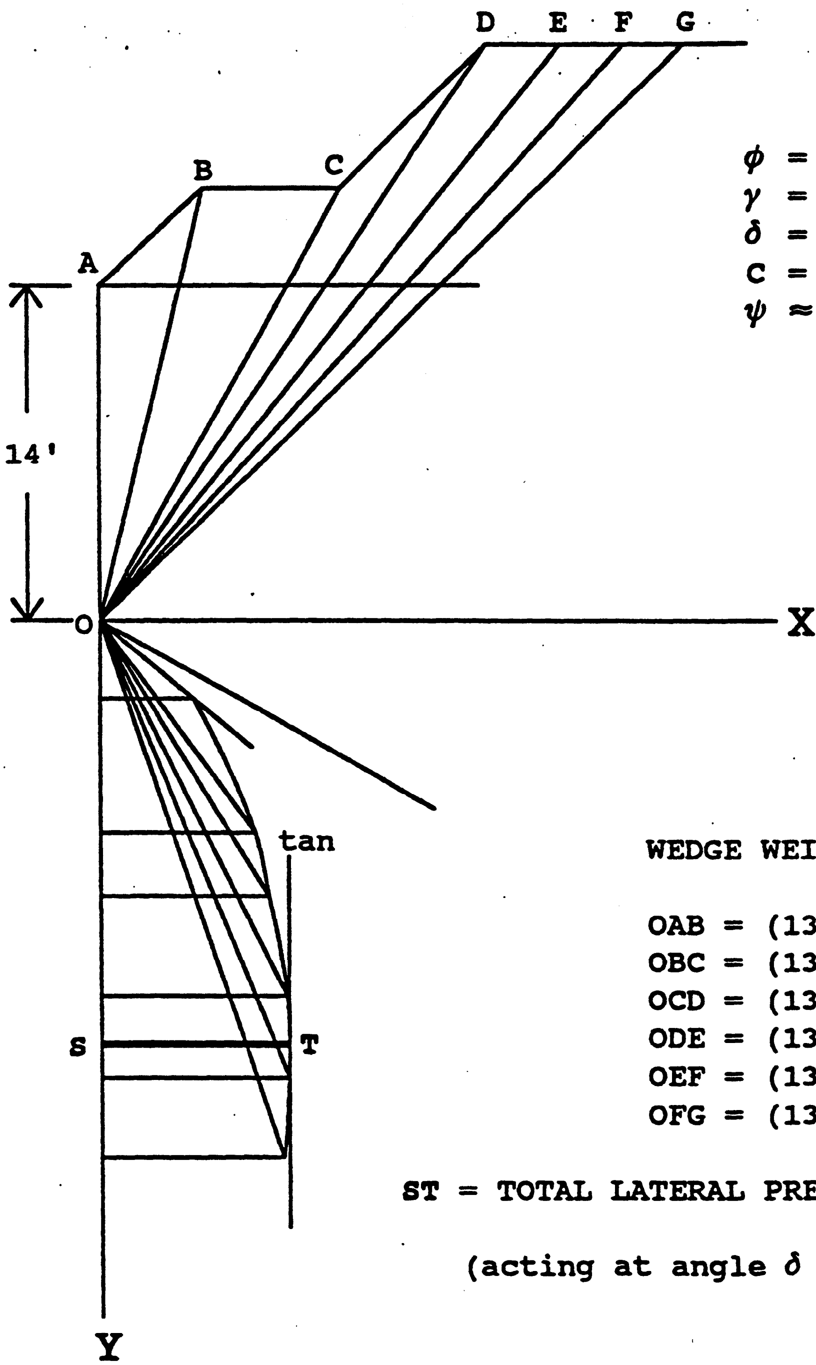
EQUIVALENT SOIL



area = (AB)(h)/2
h = (2)(29.1)/7.44 = 7.83'
CD = (h + H)tan ψ = 11.61'
tan β = h/CD = 0.67
∴ β = 34°, β/ϕ = 1.0
From **FIGURE 8**, K_a = 0.78
P = $(K_a)(\gamma)(H)^2/2$
P = $(0.78)(130)(14)^2/2$
= 9,937 Lb/LF

H_S = area/7.44 = 3.91'
H' = H + H_S = 14 + 3.91
= 17.91'
$K_a = \tan^2(45° - \phi/2)$ = 0.28
P = $(K_a)(\gamma)(H')^2/2$
= $(0.28)(130)(17.92)^2/2$
= 5,838 Lb/LF

TRIAL WEDGE



$\phi = 34°$
$\gamma = 130$ PCF
$\delta = 0$
C = 0
$\psi \approx \tan(45° - \phi/2) \approx 28°$

WEDGE WEIGHTS:

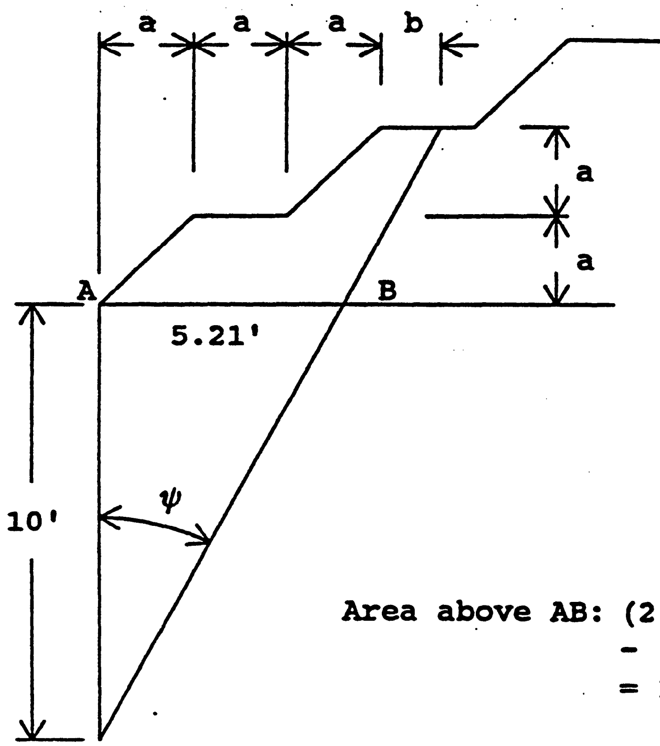
OAB = (130)(25.1 Ft^2) = 3,263
OBC = (130)(42.8 Ft^2) = 5,564
OCD = (130)(20.8 Ft^2) = 2,704
ODE = (130)(31.0 Ft^2) = 4,030
OEF = (130)(27.0 Ft^2) = 3,510
OFG = (130)(25.0 Ft^2) = 3,250

ST = TOTAL LATERAL PRESSURE (P) = <u>6,500 Lb</u>

(acting at angle δ from the horizontal)

NOT TO SCALE

EXAMPLE 2:



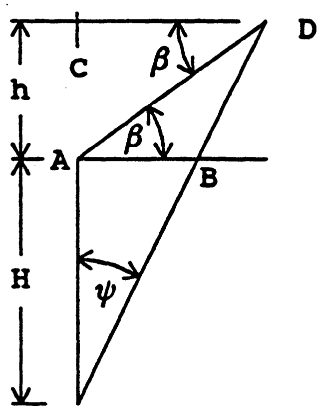
$a = 2.00'$
$b = 1.29'$

$\phi = 35°$
$\gamma = 110$ pcf
$\delta = 0$
$C = 0$
$\psi \approx \tan(45° - \phi/2) \approx 27.5°$

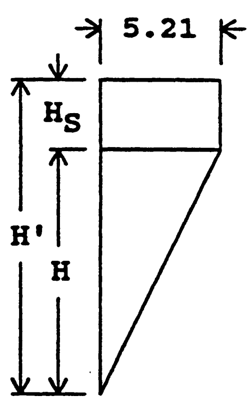
$AB = (10)(\tan 27.5°) = 5.21'$

Area above AB: $(2)(2)/2 + (2)(2) + (3.29)(4)$
$- (2)(2)/2 - (7.29 - 5.21)(4)/2$
$= 13.0\ Ft^2/LF$

EQUIVALENT SLOPE



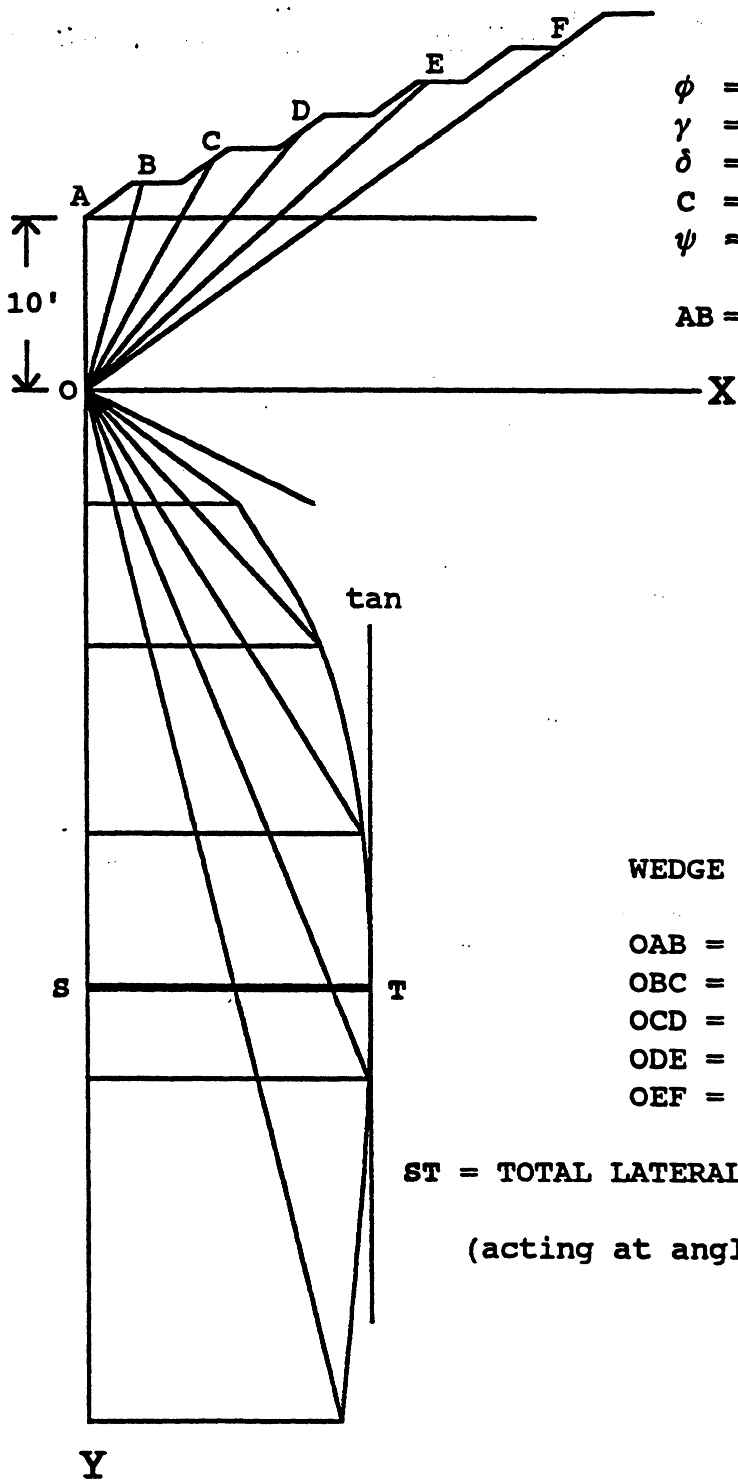
EQUIVALENT SOIL



$\text{area} = (AB)(h)/2$
$h = (2)(13.0)/5.21 = 4.99'$
$CD = (h + H)\tan\psi = 7.80'$
$\tan\beta = h/CD = 0.64$
$\therefore \beta = 32.6°,\ \beta/\phi = 0.93$
From FIGURE 8, $K_a = 0.62$
$P = (K_a)(\gamma)(H)^2/2$
$P = (0.62)(110)(10)^2/2$
$= \underline{3,410\ Lb/LF}$

$H_S = \text{area}/5.21 = 2.49'$
$H' = H + H_S = 10 + 2.49$
$= 12.49'$
$K_a = \tan^2(45° - \phi/2) = 0.27$
$P = (K_a)(\gamma)(H')^2/2$
$= (0.27)(110)(12.49)^2/2$
$= \underline{2,317\ Lb/LF}$

TRIAL WEDGE



ϕ = 35°
γ = 110 pcf
δ = 0
C = 0
$\psi \approx \tan(45° - \phi/2) \approx 27.5°$

AB = (10)(tan 27.5°) = 5.21'

WEDGE WEIGHTS:

OAB = (110)(12.40 Ft^2) = 1,364
OBC = (110)(14.93 Ft^2) = 1,642
OCD = (110)(19.67 Ft^2) = 2,164
ODE = (110)(26.60 Ft^2) = 2,926
OEF = (110)(36.40 Ft^2) = 4,004

ST = TOTAL LATERAL PRESSURE (P) = <u>2,500 Lb</u>

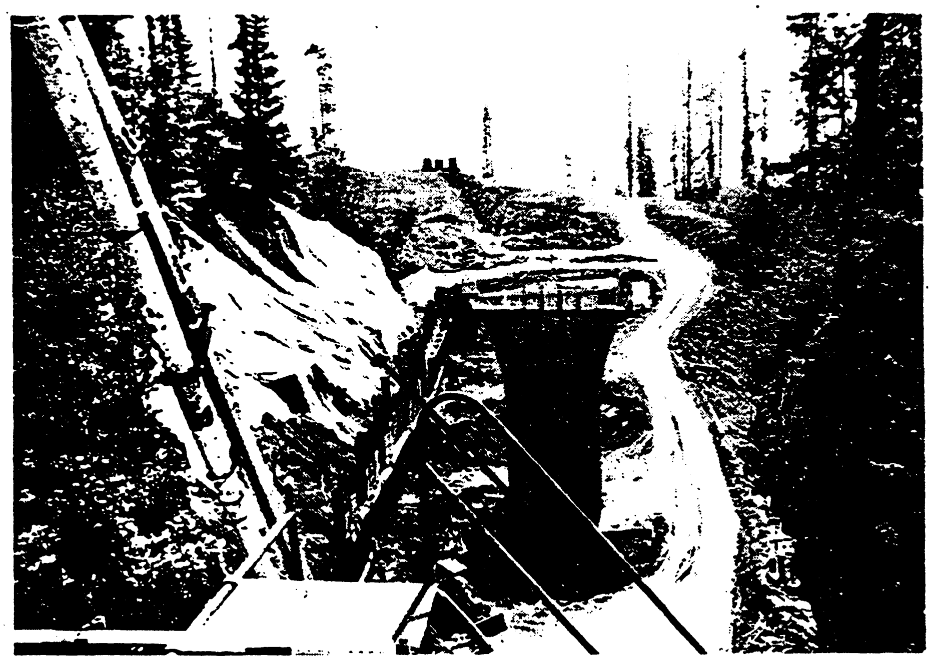
(acting at angle δ from the horizontal)

NOT TO SCALE

SUMMARY OF RESULTS

Trial Wedge	Equivalent Slope	% difference
6,500	9,937	52.9
2,500	3,410	36.4

Trial Wedge	Equivalent Soil	% difference
6,500	5,838	-10.2
2,500	2,317	-7.3



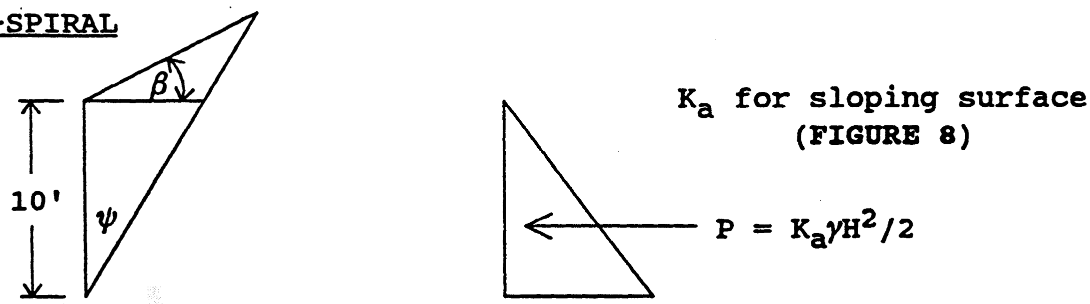
CONSTANT SLOPE COMPARISON

In determining -lateral earth pressures for embankments with a constant slope the Log-Spiralmethod is the easiest and most preferred. solution. The table on the following page compares the Log-Spiral method and two of the more common "shortcut" solutions. From this table it can be seen that the difference between these methods and the more theoretically correct solution (Log-Spiral) can be quite large depending on the parameters used.

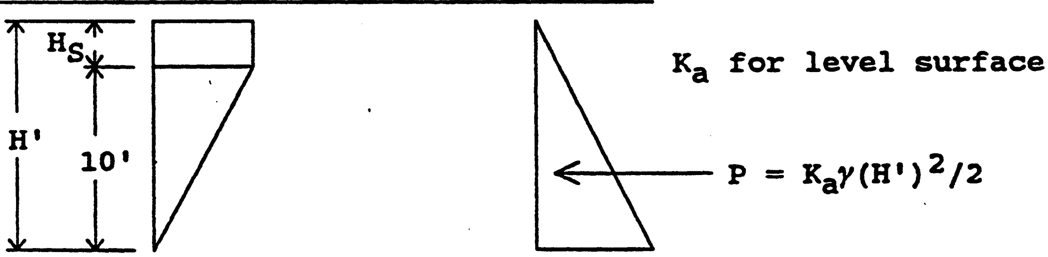
As the ratio between the embankment slope angle (β) and the soil internal friction angle (ϕ) increases, so does the difference between the various methods. When this ratio approaches 0.8, the difference becomes significant. For all practicality when the ratio is 0.6 or less, the slope condition can be treated as a level surface as shown below and by the comparison table on page 6-21. This leaves only a small range where these "shortcut " methods are of any value. Since this is not very practical and as the Log-Spiral method is quite easy to employ, these other methods will not be used for analysis or review.

For all three conditions, γ = 100 pcf, δ = 0, and C = 0.

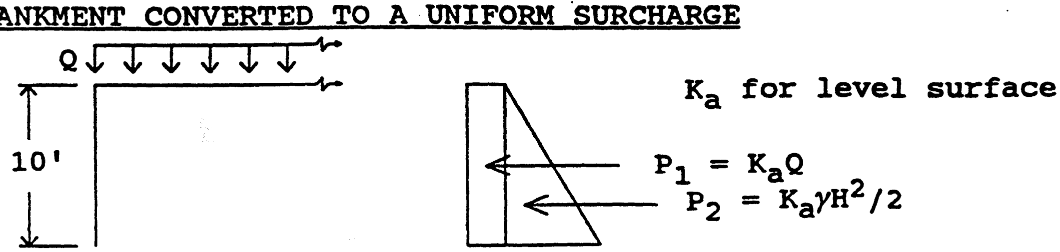
LOG-SPIRAL



EMBANKMENT CONVERTED TO A LEVEL SURFACE



EMBANKMENT CONVERTED TO A UNIFORM SURCHARGE



CONSTANT SLOPE EMBANKMENT
COMPARISON TABLE

	β/ϕ = 0.4	β/ϕ = 0.6	β/ϕ = 0.8	β/ϕ = 1.0
ϕ = 10°				
Log-Spiral	3,700	4,000	4,300	5,500
Conv. to H'	3,742	3,869	4,007	4,158
Uniform Q	3,739	3,861	3,991	4,131
ϕ = 16°				
Log-Spiral	3,150	3,400	3,750	5,250
Conv. to H'	3,108	3,270	3,457	3,677
Uniform Q	3,102	3,255	3,427	3,623
ϕ = 20°				
Log-Spiral	2,750	3,000	3,350	4,950
Conv. to H'	2,725	2,897	3,104	3,360
Uniform Q	2,718	2,879	3,065	3,288
ϕ = 26°				
Log-Spiral	2,250	2,500	2,850	4,500
Conv. to H'	2,211	2,384	2,604	2,899
Uniform Q	2,203	2,362	2,557	2,805
ϕ = 30°				
Log-Spiral	1,850	2,150	2,500	4,300
Conv. to H'	1,908	2,074	2,293	2,604
Uniform Q	1,900	2,052	2,244	2,500
ϕ = 35°				
Log-Spiral	1,600	1,750	2,150	3,800
Conv. to H'	1,559	1,707	1,916	2,235
Uniform Q	1,551	1,687	1,867	2,124
ϕ = 40°				
Log-Spiral	1,250	1,400	1,700	3,350
Conv. to H'	1,259	1,388	1,577	1,895
Uniform Q	1,252	1,369	1,531	1,782
ϕ = 45°				
Log-Spiral	1,000	1,100	1,375	2,900
Conv. to H'	999	1,105	1,270	1,575
Uniform Q	994	1,090	1,230	1,468

TRAFFIC LOADS

Traffic near an excavation is one of the more commonly occurring surcharge loads. Trying to analyze every possible scenario would not only be time consuming but not very practical. For normal situations. a surcharge load of 300 psf spreadover the width of the traveled way should be sufficient.

The following example compares the pressure diagrams for a HS20 truck. (using point loads) centered in a 12' lane to a load of Q = 300 psf (using the Boussinesq Strip method). The depth of excavation is 10'.

HS20 TRUCK

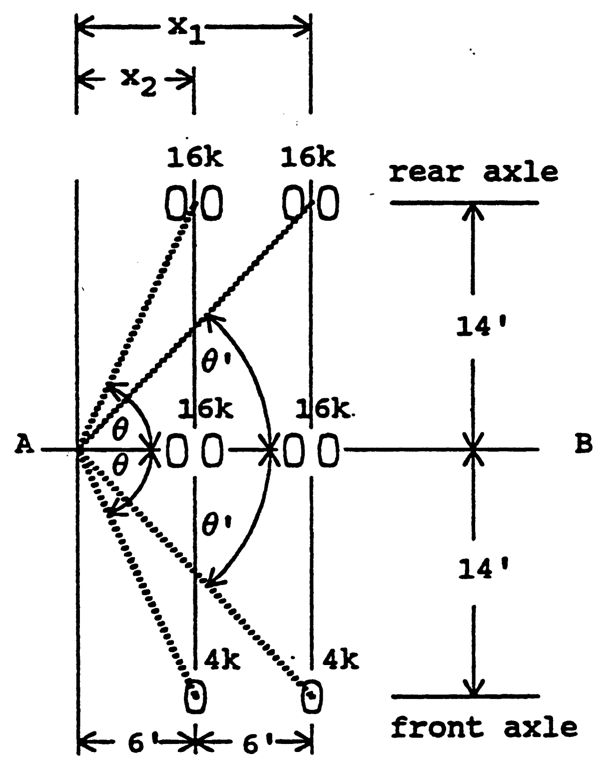
For a detailed explanation on point loads see the USS Steel Sheet Piling Design Manual (pg 15).

$x_1 = m_1 H$
$\therefore m_1 = (12/10) = 1.2$

$x_2 = m_2 H$
$\therefore m_2 = (6/10) = 0.6$

n = depth/H

Depth	n
2'	0.2
4'	0.4
6'	0.6
8'	0.8
10'	1.0



For line AB, $\sigma_H = 1.77 \dfrac{Q_P \quad (m^2 n^2)}{H^2 \quad (m^2 + n^2)^3}$ (for m > 0.4)

For loads at an angle to AB, $\sigma_H' = \sigma_H \cos^2(1.1\theta)$

Front and rear rt wheels: $\theta = 66.8°$, $\therefore \cos^2[(1.1)(66.8°)] = 0.08$
Front and rear lt wheels: $\theta' = 49.4°$, $\therefore \cos^2[(1.1)(49.4°)] = 0.34$

1.) Rt rear wheels:
$\sigma_H = (0.08)(1.77)(16{,}000)(0.6^2)(n^2)/[10^2(0.6^2 + n^2)^3]$

2.) Lt rear wheels:
$\sigma_H = (0.34)(1.77)(16{,}000)(1.2^2)(n^2)/[10^2(1.2^2 + n^2)^3]$

3.) Rt center wheels:
$\sigma_H = (1.77)(16{,}000)(0.6^2)(n^2)/[10^2(0.6^2 + n^2)^3]$

4.) Lt center wheels:
$\sigma_H = (1.77)(16{,}000)(1.2^2)(n^2)/[10^2(1.2^2 + n^2)^3]$

5.) Rt front wheels:
$\sigma_H = (0.08)(1.77)(4{,}000)(0.6^2)(n^2)/[10^2(0.6^2 + n^2)^3]$

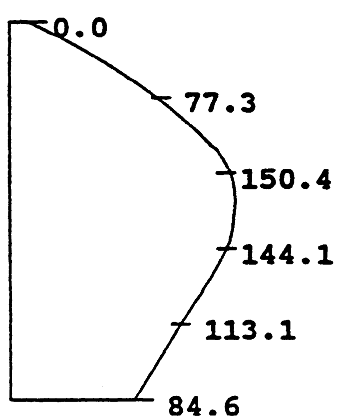
6.) Lt front wheels:
$\sigma_H = (0.34)(1.77)(4{,}000)(1.2^2)(n^2)/[10^2(1.2^2 + n^2)^3]$

Combine and simplify similar equations:

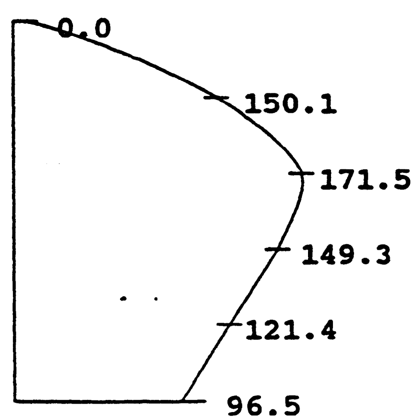
a.) $\sigma_H = (112.2)(n^2)/(0.36 + n^2)^3$
b.) $\sigma_H = (581.1)(n^2)/(1.44 + n^2)^3$

Depth	n	a.) σ_H	b.) σ_H	$\Sigma\sigma_H$
0'	0.0	0.0	0.0	0.0
2'	0.2	70.1	7.2	77.3
4'	0.4	127.7	22.7	150.4
6'	0.6	108.2	35.9	144.1
8'	0.8	71.8	41.3	113.1
10'	1.0	44.6	40.0	84.6

HS20 Truck
(point loading without impact)

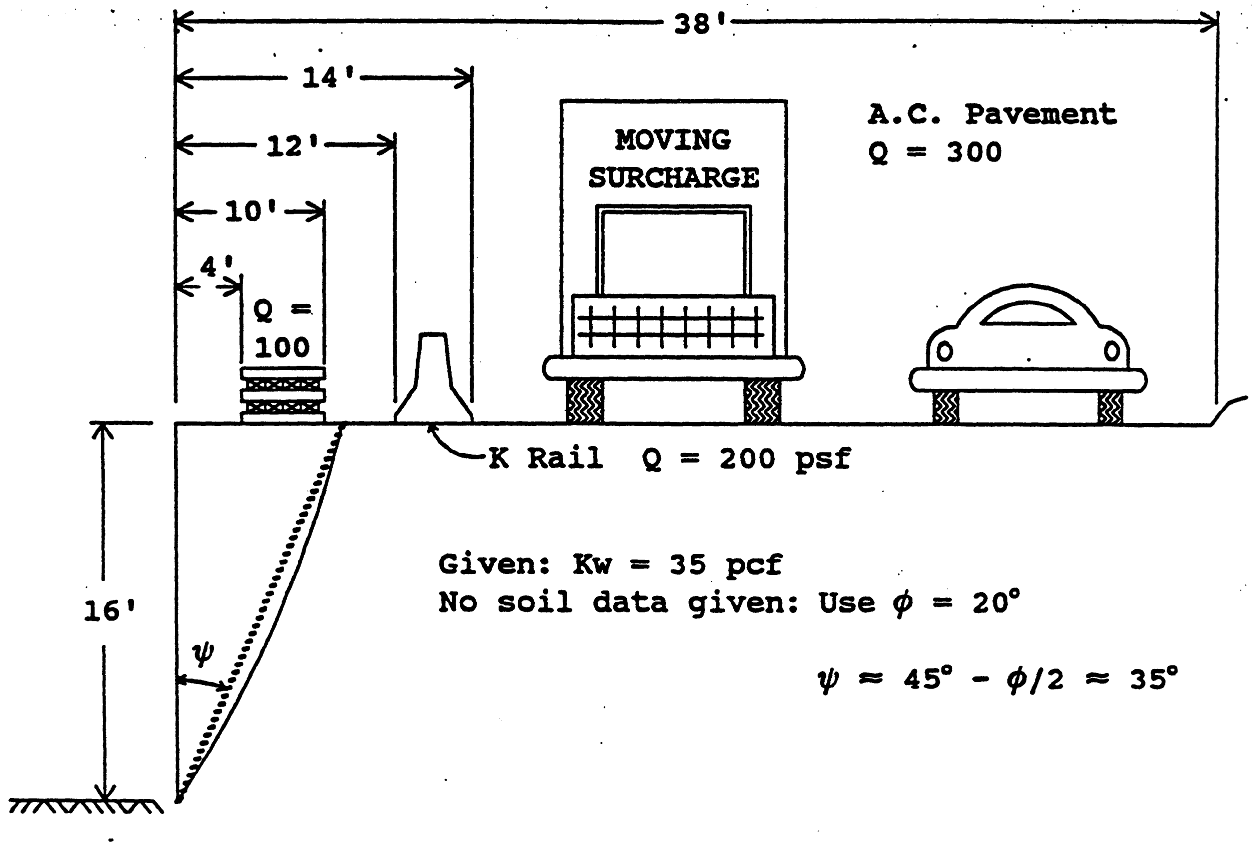


12' strip
(Q = 300 psf)



CONCLUSION: Strip load of Q = 300 psf compares favorably to a point load evaluation for HS20 truck loadings.

SAMPLE PROBLEM NO. 8 - SURCHARGE LOADS



Surcharge Lateral Pressures (psf)

Depth	Q = 100	Q = 200	Q = 300	Sum
0.1	1.9	0.3	1.7	72*
1	17.9	3.0	17.1	72*
2	30.2	5.8	33.8	72*
4	35.7	10.1	63.7	109.5
6	29.5	12.3	87.1	128.9
8	21.9	12.7	130.3	164.9
10	15.9	11.9	112.6	140.4
12	11.5	10.5	116.4	138.4
14	8.5	9.0	116.1	133.6
16	6.3	7.6	112.9	126.8

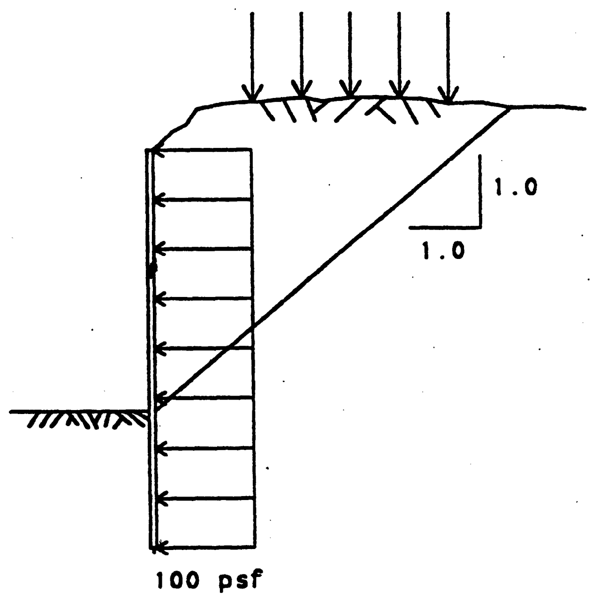
* Minimum construction surcharge load.

Add soil pressures to sum of surcharge loads to derive combined pressure diagram.

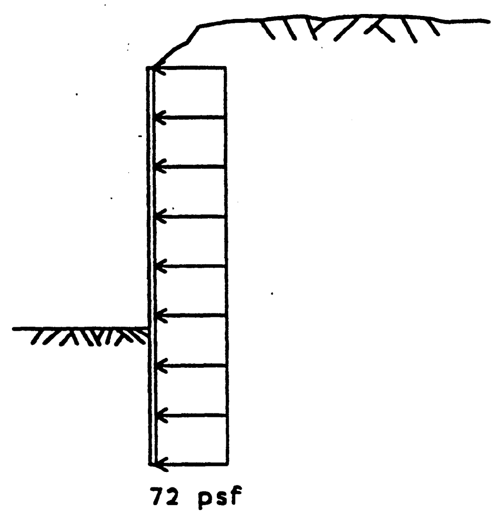
ALTERNATIVE SURCHARGE LOADING

An acceptable alternative to the Boussinesq analysis consists of imposing imaginary surcharges behind the shoring such that the resulting pressure diagram is a rectangle extending to the computed depth of the shoring members and of a uniform width of 100 psf. This 100 psf loading is analogous to the 72 psf pressure diagram used for minimum surcharge loading.

Generally, traffic and equipment surcharge loads beyond the limits of an inclined plane rising at an angle of 1.0 horizontal to 1.0 vertical from the bottom of the excavation may be ignored. Other loadings due to structures, or stockpiles of soil, materials or heavy equipment will need to be considered separately.



SHORING WITH TRAFFIC.



SHORING WITHOUT TRAFFIC

Shoring without traffic, structures or stockpiles.
Minimum Surcharge

RAILROAD SURCHARGES

Railroads adjacent to an excavation will result in very large surcharge pressures, and since railroad loadings are consideredto be a dynamic load, the short term load duration overstress factor of 1.33 cannot be used, Note also that wall friction (6) is not allowed for basic earth pressure computations.

The American Railway Engineering Association (AREA) specifies the use of a Boussinesq Formula for a railroad surcharge. The Southern Pacific Transportation Company (SPTC) concluded that values given by the AREA Boussinesq Formula were not realistic, (the maximum pressure was too high and occurred to on near the ground surface) so they developed their own live load surcharge earth pressure curve. The pressures from the SPTC curve are about half those given by the AREA Boussinesq curve. The SPTC curve is a part of the SPTC Supplement to Section 20a of the AREA specifications (See Appendix C). The SPTC curve, for Cooper E72 and E80 railroad loadings, is shown on the next page.

The SPTC Live Load Surcharge curve is to be used for all railroads. Note that all major railroads now require E80 design.

For a simplified engineering analysis (H < l0'), the railroad loading surcharge pressure may be assumed rectangular with an ordinate (P_S) equal to 0.8 of the maximum. pressure ordinate as given by the appropriate railroad curve. When using the railroad live load curves, the plot of the curve starts at the top of the railroad roadbed (bottom of ties), The portion that is used extends from the top of the excavation to the bottom of the shoring system. Depth of ballast may normally be assumed to be 1.5 feet.

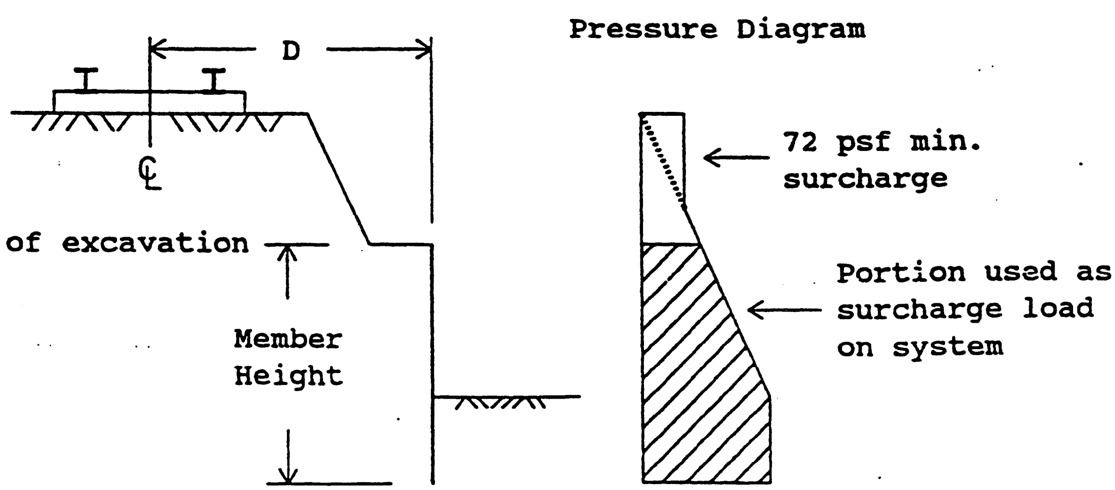
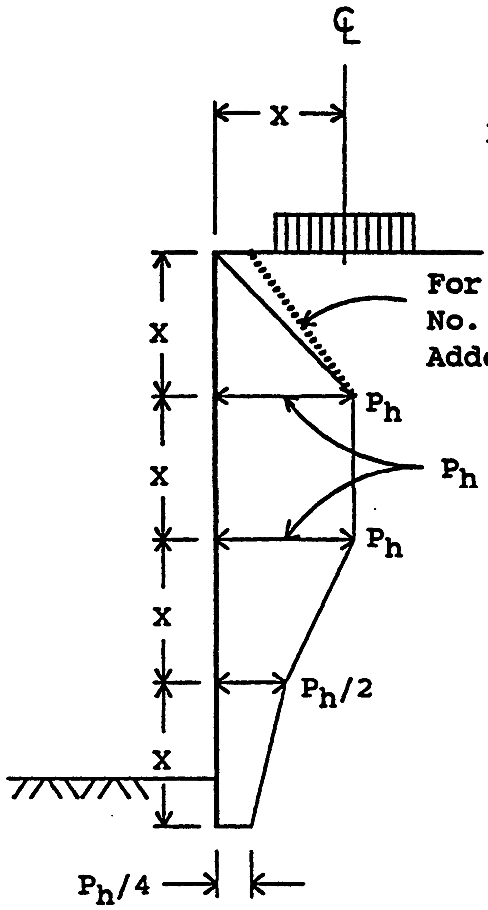


CHART 3.6 LATERAL PRESSURE FOR COOPER RAILROAD LIVE LOAD



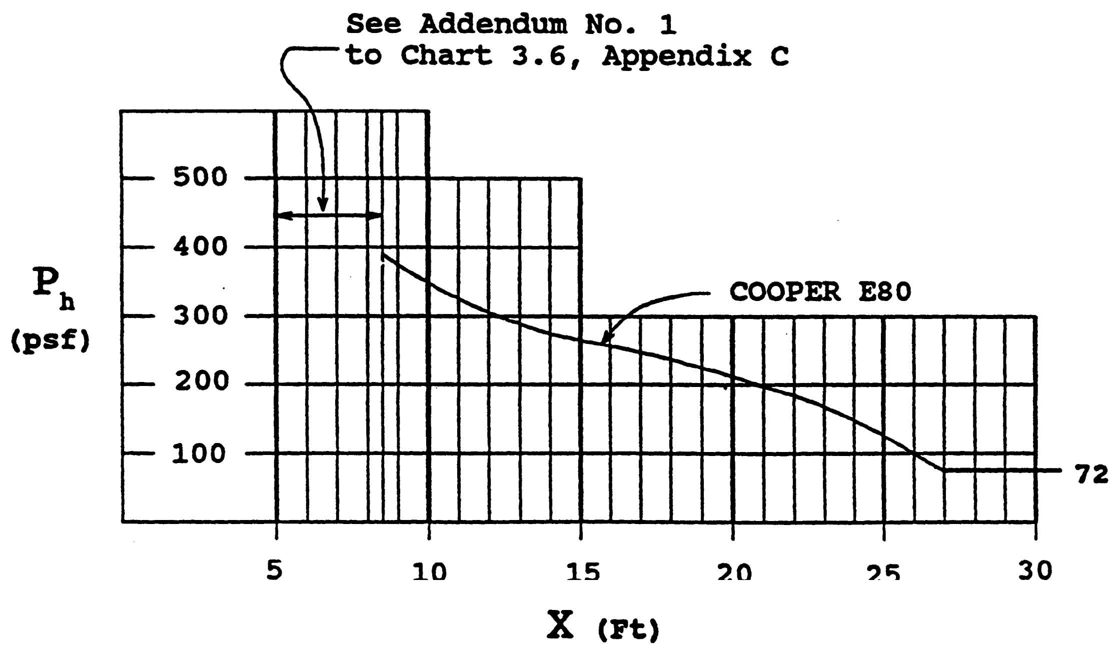
X = Distance from centerline of RR to face of excavation.

For X < 8'6" only. Use table in Addendum No. 1 to Chart 3.6. See Appendix C for Addendum No. 1.

P_h = Lateral pressure from chart below.

NOTES:

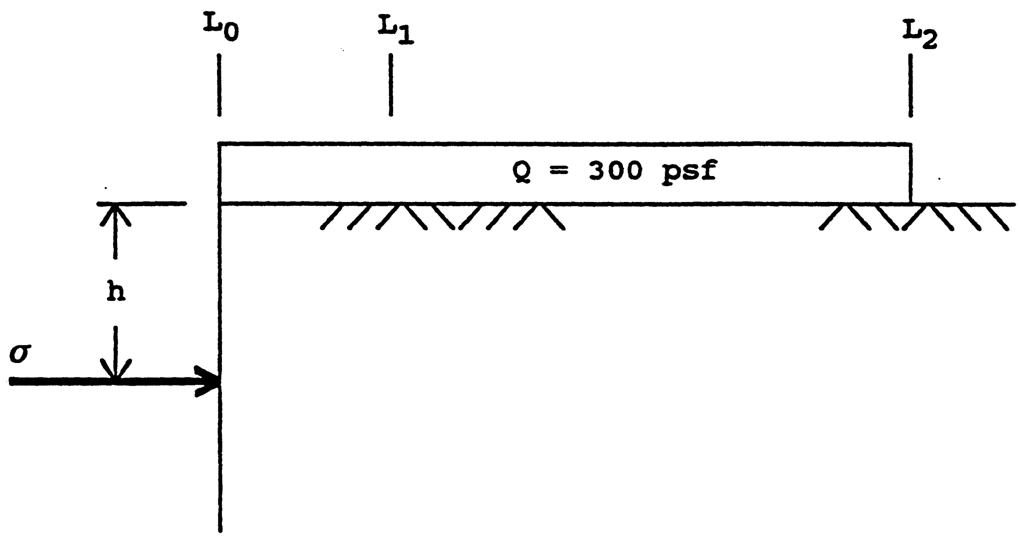
1. A minimum of 72 psf lateral pressure must be used as specified in 3.4 (equivalent to 2' of earth).
2. For each additional depth increase of X, decrease intensity of the pressure by 50%.



TABULAR VALUES FOR STRIP LOADS

The following- tabular values may be used to obtain horizontal pressures due to surcharge loadings.

Tabular values are for a Boussinesq strip surcharge of Q = 300 psf for a length of surcharge beginning at the face of the excavation (L_0) to the end of the strip load (L_2). Surcharge pressures are listed for one foot increments of excavation to a depth of 20 feet.



For surcharges not beginning at the face of the excavation (L_1 subtract tabular values for distance L_1 from the tabular values for L_2. Prorate other Q values by using the ratio Q/300 (difference in L values).

Note: When L_0 = 0, the pressure at h = 0 is Q (300 psf).

EXAMPLE:

Begin Boussinesq strip load 6 feet from excavation, L_1 = 6'
End Boussinesq strip load 20 feet from excavation, L_2 = 20'
Surcharge load Q = 250 psf
Determine surcharge pressure at h = 12'

σ_{12} = 250/300(112.53 - 12.16) = 83.6 psf

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_0 TO L_1 OR L_2

h	1	2	3	4	5	6	7	8
1	54.51	135.06	181.25	208.27	225.57	237.49	246.16	252.74
2	12.16	54.51	99.55	135.06	161.47	181.25	196.40	208.27
3	4.15	24.15	54.51	85.43	112.53	135.06	153.52	168.69
4	1.85	12.16	31.23	54.51	77.97	99.55	118.58	135.06
5	0.97	6.81	18.95	35.70	54.51	73.39	91.21	107.48
6	0.57	4.15	12.16	24.15	38.76	54.51	70.29	85.43
7	0.36	2.70	8.18	16.88	28.13	40.97	54.51	68.07
8	0.24	1.85	5.73	12.16	20.85	31.23	42.64	54.51
9	0.17	1.32	4.15	8.99	15.77	24.15	33.70	43.94
10	0.13	0.97	3.10	6.81	12.16	18.95	26.92	35.70
11	0.09	0.74	2.37	5.27	9.53	15.08	21.73	29.24
12	0.07	0.57	1.85	4.15	7.59	12.16	17.73	24.15
13	0.06	0.45	1.47	3.33	6.13	9.92	14.61	20.11
14	0.05	0.36	1.19	2.70	5.02	8.18	12.16	16.88
15	0.04	0.30	0.97	2.22	4.15	6.81	10.20	14.27
16	0.03	0.24	0.81	1.85	3.47	5.73	8.63	12.16
17	0.03	0.20	0.67	1.55	2.93	4.86	7.36	10.42
18	0.02	0.17	0.57	1.32	2.50	4.15	6.32	8.99
19	0.02	0.15	0.49	1.13	2.14	3.58	5.46	7.81
20	0.02	0.13	0.42	0.97	1.85	3.10	4.75	6.81

TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_o TO L_a or L_2

h	9	10	11	12	13	14	15	16
1	257.90	262.06	265.47	268.32	270.73	272.81	274.61	276.19
2	217.79	225.57	232.04	237.49	242.14	246.16	249.66	252.74
3	181.25	191.77	200.67	208.27	214.84	220.56	225.57	230.01
4	149.24	161.47	172.05	181.25	189.31	196.31	202.68	208.27
5	122.07	135.06	146.57	156.79	165.88	173.99	181.25	187.78
6	99.55	112.53	124.34	135.06	144.75	153.52	161.47	168.69
7	81.20	93.63	105.26	116.02	125.94	135.06	143.42	151.10
8	66.39	77.97	89.06	99.55	109.39	118.58	127.12	135.06
9	54.51	65.08	75.43	85.43	94.97	104.01	112.53	120.53
10	44.99	54.51	64.03	73.39	82.47	91.21	99.55	107.48
11	37.36	45.85	54.51	63.17	71.70	80.03	88.08	95.81
12	31.23	38.76	46.57	54.51	62.45	70.29	77.97	85.43
13	26.27	32.93	39.95	47.18	54.51	61.84	69.10	76.22
14	22.24	28.13	34.41	40.97	47.70	54.51	61.32	68.07
15	18.95	24.15	29.77	35.70	41.86	48.15	54.51	60.86
16	16.25	20.85	25.87	31.23	36.84	42.64	48.55	54.51
17	14.02	18.09	22.58	27.41	32.53	37.85	43.33	48.90
18	12.16	15.77	19.79	24.15	28.81	33.70	38.76	43.94
19	10.60	13.81	17.42	21.36	25.59	30.07	34.75	39.57
20	9.29	12.16	15.39	18.95	22.81	26.92	31.23	35.70

TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_0 TO L_i or L_2

h	17	18	19	20	21	22	23	24
1	277.58	278.82	279.93	280.93	281.84	282.66	283.41	284.10
2	255.47	257.90	260.09	262.06	263.84	265.47	266.95	268.32
3	233.95	237.49	240.67	243.55	246.16	248.55	250.73	252.74
4	213.28	217.79	221.87	225.57	228.95	232.04	234.87	237.49
5	193.67	199.00	203.85	208.27	212.33	216.05	219.47	222.64
6	175.26	181.25	186.74	191.77	196.40	200.67	204.62	208.27
7	158.16	164.65	170.63	176.15	181.25	185.98	190.38	194.46
8	142.42	149.24	155.58	161.47	166.95	172.05	176.81	181.25
9	128.03	135.06	141.62	147.77	153.52	158.91	163.95	168.69
10	114.98	122.07	128.76	135.06	140.99	146.57	151.84	156.79
11	103.21	110.26	116.96	123.32	129.35	135.06	140.46	145.58
12	92.63	99.55	106.19	112.53	118.58	124.34	129.83	135.06
13	83.16	89.89	96.39	102.65	108.66	114.42	119.94	125.21
14	74.70	81.20	87.51	93.63	99.55	105.26	110.75	116.02
15	67.17	73.39	79.48	85.43	91.21	96.82	102.24	107.48
16	60.47	66.39	72.23	77.97	83.59	89.06	94.39	99.55
17	54.51	60.12	65.69	71.21	76.63	81.95	87.15	92.21
18	49.21	54.51	59.81	65.08	70.29	75.43	80.48	85.43
19	44.50	49.49	54.51	59.53	64.52	69.47	74.36	79.16
20	40.30	44.99	49.74	54.51	59.28	64.03	68.74	73.39

TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_o TO L_1 or L_2

h	25	26	27	28	29	30	31	32
1	284.74	285.32	285.87	286.37	286.84	287.28	287.69	288.07
2	269.57	270.73	271.81	272.81	273.74	274.61	275.42	276.19
3	254.60	256.31	257.90	259.38	260.76	262.06	263.26	264.40
4	239.90	242.14	244.22	246.16	247.97	249.66	251.25	252.74
5	225.57	228.30	230.83	233.20	235.41	237.49	239.44	241.27
6	211.67	214.84	217.79	220.56	223.14	225.57	227.86	230.01
7	198.27	201.83	205.16	208.27	211.20	213.96	216.55	219.00
8	185.41	189.31	192.96	196.40	199.63	202.68	205.56	208.27
9	173.14	177.32	181.25	184.96	188.46	191.77	194.90	197.86
10	161.47	165.88	170.05	173.99	177.72	181.25	184.60	187.78
11	150.43	155.03	159.38	163.51	167.43	171.15	174.69	178.05
12	140.02	144.75	149.24	153.52	157.59	161.47	165.17	168.69
13	130.24	135.06	139.65	144.04	148.23	152.23	156.05	159.70
14	121.08	125.94	130.60	135.06	139.33	143.42	147.34	151.10
15	112.53	117.39	122.07	126.57	130.90	135.06	139.05	142.89
16	104.56	109.39	114.07	118.58	122.93	127.12	131.16	135.06
17	97.14	101.93	106.57	111.06	115.41	119.62	123.68	127.61
18	90.26	94.97	99.55	104.01	108.33	112.53	116.59	120.53
19	83.88	88.49	93.00	97.40	101.68	105.85	109.89	113.83
20	77.97	82.47	86.89	91.21	95.43	99.55	103.57	107.48

TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_0 TO L_1 or L_2

h	33	34	35	36	37	38	39	40
1	288.43	288.77	289.09	289.40	289.68	289.95	290.21	290.45
2	76.91	277.58	278.22	278.82	279.39	279.93	280.45	280.93
3	265.47	266.47	267.42	268.32	269.16	269.97	270.73	271.46
4	254.15	255.47	256.72	257.90	259.02	260.09	261.10	262.06
5	242.99	244.62	246.16	247.62	249.00	250.31	251.56	252.74
6	232.04	233.95	235.77	237.49	239.12	240.67	242.14	243.55
7	221.31	223.50	225.57	227.54	229.41	231.18	232.87	234.48
8	210.85	213.28	215.60	217.79	219.88	221.87	223.76	225.57
9	200.67	203.33	205.87	208.27	210.57	212.75	214.84	216.83
10	190.80	193.67	196.40	199.00	201.48	203.85	206.11	208.27
11	181.25	184.31	187.21	189.99	192.64	195.17	197.60	199.92
12	172.05	175.26	178.32	181.25	184.06	186.74	189.31	191.77
13	163.20	166.54	169.74	172.80	175.74	178.55	181.25	183.85
14	154.71	158.16	161.47	164.65	167.70	170.63	173.44	176.15
15	146.57	150.12	153.52	156.79	159.94	162.97	165.88	168.69
16	138.80	142.42	145.89	149.24	152.47	155.58	158.58	161.47
17	131.40	135.06	138.59	142.00	145.29	148.47	151.53	154.50
18	124.34	128.03	131.60	135.06	138.39	141.62	144.75	147.77
19	117.64	121.35	124.94	128.42	131.79	135.06	138.22	141.29
20	111.28	114.98	118.58	122.07	125.46	128.76	131.95	135.06

TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_o TO L_1 or L_2

h	41	42	43	44	45	46	47	48
1	290.69	290.91	291.12	291.32	291.51	291.70	291.88	292.04
2	281.40	281.84	282.26	282.66	283.05	283.41	283.77	284.10
3	272.15	272.81	273.44	274.04	274.61	275.16	275.68	276.19
4	262.97	263.84	264.67	265.47	266.22	266.95	267.65	268.32
5	253.87	254.95	255.98	256.96	257.90	258.80	259.67	260.50
6	244.88	246.16	247.38	248.55	249.66	250.73	251.76	252.74
7	236.02	237.49	238.89	240.23	241.52	242.75	243.94	245.07
8	227.30	228.95	230.53	232.04	233.49	234.87	236.21	237.49
9	218.73	220.56	222.30	223.97	225.57	227.11	228.59	230.01
10	210.34	212.33	214.22	216.05	217.79	219.47	221.09	222.64
11	202.14	204.27	206.31	208.27	210.16	211.97	213.71	215.39
12	194.13	196.40	198.58	200.67	202.68	204.62	206.48	208.27
13	186.33	188.73	191.02	193.24	195.36	197.42	199.39	201.30
14	178.75	181.25	183.66	185.98	188.22	190.38	192.46	194.46
15	171.39	173.99	176.50	178.92	181.25	183.51	185.68	187.78
16	164.26	166.95	169.55	172.05	174.47	176.81	179.07	181.25
17	157.36	160.12	162.80	165.38	167.88	170.29	172.63	174.89
18	150.69	153.52	156.26	158.91	161.47	163.95	166.36	168.69
19	144.26	147.14	149.93	152.64	155.26	157.80	160.27	162.66
20	138.07	140.99	143.82	146.57	149.24	151.84	154.35	156.79

TABLE 18

SURCHARGES

PRESSURE AT DEPTH h FOR UNIFORM LOADING FROM L_o TO L_1 or L_2

h	49	50	51	52	53	54	55	56
1	292.21	292.36	292.51	292.66	292.79	292.93	293.06	293.18
2	284.43	284.74	285.04	285.32	285.60	285.87	286.12	286.37
3	276.67	277.14	277.58	278.01	278.43	278.82	279.21	279.58
4	268.96	269.57	270.16	270.73	271.28	271.81	272.32	272.81
5	261.29	262.06	262.79	263.50	264.18	264.83	265.47	266.08
6	253.69	254.60	255.47	256.31	257.12	257.90	258.66	259.38
7	246.16	247.21	248.22	249.19	250.13	251.03	251.90	252.74
8	238.72	239.90	241.04	242.14	243.20	244.22	245.21	246.16
9	231.37	232.69	233.95	235.18	236.35	237.49	238.59	239.64
10	224.13	225.57	226.96	228.30	229.59	230.83	232.04	233.20
11	217.01	218.56	220.07	221.52	222.91	224.27	225.57	226.84
12	210.01	211.67	213.28	214.84	216.34	217.79	219.20	220.56
13	203.13	204.91	206.62	208.27	209.87	211.42	212.92	214.37
14	196.40	198.27	200.08	201.83	203.52	205.16	206.74	208.27
15	189.81	191.77	193.67	195.50	197.28	199.00	200.67	202.28
16	183.37	185.41	187.39	189.31	191.16	192.96	194.71	196.40
17	177.08	179.20	181.25	183.25	185.18	187.05	188.86	190.62
18	170.95	173.14	175.26	177.32	179.32	181.25	183.14	184.96
19	164.98	167.23	169.41	171.53	173.59	175.59	177.53	179.42
20	159.17	161.47	163.71	165.88	168.00	170.05	172.05	173.99

TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_o TO L_l or L_a

h	57	58	59	60	61	62	63	64
1	293.30	293.42	293.53	293.63	293.74	293.84	293.94	294.03
2	286.61	286.84	287.06	287.28	287.49	287.69	287.88	288.07
3	279.93	280.28	280.61	280.93	281.24	281.55	281.84	282.12
4	273.28	273.74	274.18	274.61	275.02	275.42	275.81	276.19
5	266.66	267.23	267.78	268.32	268.83	269.33	269.81	270.28
6	260.09	260.76	261.42	262.06	262.67	263.26	263.84	264.40
7	253.56	254.34	255.10	255.84	256.55	257.24	257.90	258.55
8	247.08	247.97	248.83	249.66	250.47	251.25	252.01	252.74
9	240.67	241.66	242.62	243.55	244.45	245.32	246.16	246.98
10	234.33	235.41	236.47	237.49	238.48	239.44	240.37	241.27
11	228.06	229.24	230.39	231.49	232.57	233.61	234.63	235.61
12	221.87	223.14	224.38	225.57	226.73	227.86	228.95	230.01
13	215.77	217.13	218.45	219.72	220.96	222.17	223.34	224.47
14	209.76	211.20	212.60	213.96	215.27	216.55	217.79	219.00
15	203.85	205.37	206.84	208.27	209.66	211.01	212.33	213.60
16	198.04	199.63	201.18	202.68	204.14	205.56	206.93	208.27
17	192.34	194.00	195.61	197.18	198.70	200.18	201.62	203.03
18	186.74	188.46	190.14	191.77	193.36	194.90	196.40	197.86
19	181.25	183.04	184.77	186.46	188.11	189.70	191.26	192.78
20	175.88	177.72	179.51	181.25	182.95	184.60	186.21	187.78

TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_0 TO L_1 or L_2

h	65	66	67	68	69	70	71	72
1	294.12	294.21	294.30	294.38	294.46	294.54	294.62	294.70
2	288.25	288.43	288.60	288.77	288.93	289.09	289.25	289.40
3	282.40	282.66	282.92	283.17	283.41	283.65	283.88	284.10
4	276.55	276.91	277.25	277.58	277.91	278.22	278.53	278.82
5	270.73	271.17	271.60	272.01	272.42	272.81	273.19	273.56
6	264.94	265.47	265.98	266.47	266.95	267.42	267.87	268.32
7	259.18	259.79	260.38	260.95	261.51	262.06	262.58	263.10
8	253.46	254.15	254.82	255.47	256.11	256.72	257.32	257.90
9	247.78	248.55	249.30	250.03	250.73	251.42	252.09	252.74
10	242.14	242.99	243.82	244.62	245.40	246.16	246.90	247.62
11	236.56	237.49	238.39	239.26	240.11	240.94	241.75	242.53
12	231.04	232.04	233.01	233.95	234.87	235.77	236.64	237.49
13	225.57	226.64	227.69	228.70	229.68	230.64	231.58	232.49
14	220.17	221.31	222.42	223.50	224.55	225.57	226.57	227.54
15	214.84	216.05	217.22	218.36	219.47	220.56	221.61	222.64
16	209.58	210.85	212.08	213.28	214.46	215.60	216.71	217.79
17	204.39	205.72	207.01	208.27	209.50	210.70	211.87	213.00
18	199.28	200.67	202.02	203.33	204.62	205.87	207.09	208.27
19	194.25	195.69	197.10	198.46	199.80	201.10	202.37	203.61
20	189.31	190.80	192.25	193.67	195.05	196.40	197.72	199.00

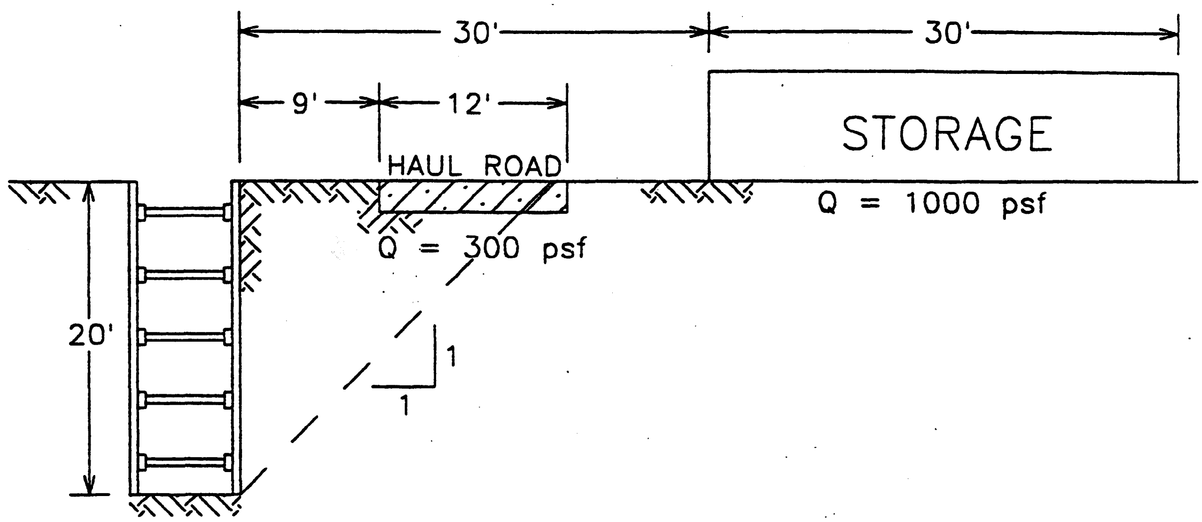
TABLE 18

PRESSURE AT DEPTH h FOR UNIFORM LOADINGS FROM L_o TO L_1 or L_2

h	73	74	75	76	77	78	79	80
1	294.77	294.84	294.91	294.97	295.04	295.10	295.17	295.23
2	289.54	289.68	289.82	289.95	290.08	290.21	290.33	290.45
3	284.32	284.53	284.74	284.94	285.13	285.32	285.51	285.69
4	279.11	279.39	279.67	279.93	280.19	280.45	280.69	280.93
5	273.92	274.27	274.61	274.94	275.27	275.58	275.89	276.19
6	268.75	269.16	269.57	269.97	270.36	270.73	271.10	271.46
7	263.60	264.08	264.55	265.02	265.47	265.90	266.33	266.75
8	258.47	259.02	259.56	260.09	260.60	261.10	261.58	262.06
9	253.38	254.00	254.60	255.18	255.76	256.31	256.86	257.39
10	248.32	249.00	249.66	250.31	250.94	251.56	252.16	252.74
11	243.30	244.04	244.77	245.47	246.16	246.83	247.49	248.13
12	238.31	239.12	239.90	240.67	241.42	242.14	242.85	243.55
13	233.38	234.24	235.08	235.90	236.71	237.49	238.25	239.00
14	228.48	229.41	230.30	231.18	232.04	232.87	233.69	234.48
15	223.64	224.62	225.57	226.50	227.41	228.30	229.16	230.01
16	218.85	219.88	220.89	221.87	222.83	223.76	224.68	225.57
17	214.11	215.20	216.25	217.29	218.29	219.28	220.24	221.18
18	209.44	210.57	211.67	212.75	213.81	214.84	215.85	216.83
19	204.82	206.00	207.15	208.27	209.37	210.45	211.50	212.53
20	200.26	201.48	202.68	203.85	204.99	206.11	207.21	208.27

TABLE 18

EXAMPLE OF ALTERNATIVE SURCHARGE AND TABULAR VALUES:



1) Determine surcharge pressures at 5 foot increments of depth starting at the ground surface.

2) Compare tabular strip load values to the alternative loading.

Sample calculations for depth = 10 feet:

At haul road: σ_{10} = 140.99 - 44.99 = 96.00 psf
For building: σ_{10} = 1000/{300(237.49 - 181.25)} = 187.47 psf

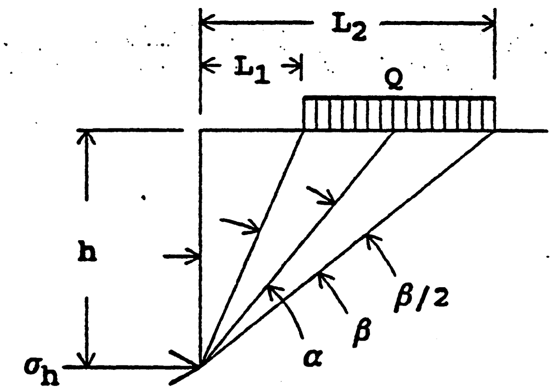
Building σ_{10} + Road σ_{10} = 283.47 psf
Building σ_{10} + Road @ 100 psf = 287.47 psf

COMBINE SURCHARGES:

Depth	Building σ	Road σ	Sum of σ's	Building σ + 100 psf
0	0.0	0.0	72.00 min.	100.00
5	102.77	90.26	193.03	202.77
10	187.47	96.00	283.47	287.47
15	244.03	72.26	316.29	344.03
20	272.33	49.99	322.32	372.33

CALCULATOR PROGRAMS FOR STRIP LOADS

BOUSSINESQ STRIP LOAD PROGRAM FOR HP 41CV



Relationship used:

$\alpha + \beta/2 + (\alpha - \beta/2) = 2\alpha$

$\alpha + \beta/2 - (\alpha - \beta/2) = \beta$

$\sigma_h = (2Q/\pi)(\beta_R - \sin\beta\cos 2\alpha)$

To Initiate Program:

[ ] GTO [•] [•]
[PRGM]
[ ]LBL [ALPHA] BOUSNQ [ALPHA]
[ALPHA] h = ? [ALPHA]
XEQ [ALPHA] PROMPT [ALPHA]
STO 04
RCL 03
[X⪌Y]
÷
[ ]TAN
STO 05
RCL 02
RCL 04
÷
[ ]TAN
STO 06
−
[ ] π
×
180
÷
RCL 05
RCL 06
+
COS
RCL 05
RCL 06
−
SIN
×

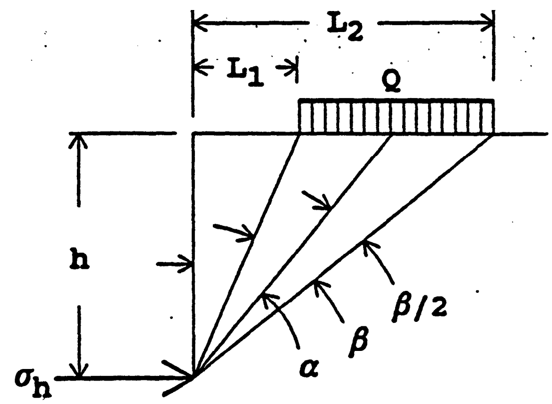
program continued:

CHS
+
2
×
RCL 01
×
[ ] π
÷
[ ] GTO [•] [•]
[PRGM]

To Run Program:

Store Q in 01
Store L_1 in 02
Store L_2 in 03
XEQ [ALPHA] BOUSNQ [ALPHA]
Calculator indicates h = ?
Enter h value
R/S
For next h:
R/S
Enter h value
R/S
etc.

BOUSSINESQ STRIP LOAD PROGRAM FOR HP 11C



Relationship used:

$\alpha + \beta/2 + (\alpha - \beta/2) = 2\alpha$

$\alpha + \beta/2 - (\alpha - \beta/2) = \beta$

Note that α never displays.
Also f & g refer to function keys

$\sigma_h = (2Q/\pi)(\beta_R - \sin\beta\cos2\alpha)$

To Initiate Program:

f FIX 4 or 5
g DEG
ENTER q STO 0
ENTER L1 STO 1
ENTER L2 STO 2
g P/R
f CLEAR PRGM

f LBL A	001-42,21,11	
STO 3	002	44 3
RCL 2	003	45 2
$\boxed{X \gtrless Y}$	004	34
÷	005	10
g TAN	006	43 25
STO 5	007	44 5
ENTER	008	36
RCL 1	009	45 1
RCL 3	010	45 3
÷	011	10
g TAN	012	43 25
STO 4	013	44 4
−	014	30
f PSE (= $\beta°$)*	015	42 31
f π	016	42 16
×	017	20
1	018	1
8	019	8
0	020	0
÷	021	10
f PSE (= $\beta°_R$)*	022	42 31
ENTER	023	36
RCL 5	024	45 5

program continued:

RCL 4	025	45 4
+	026	40
COS	027	24
f PSE (= COS2α)*	028	42 31
RCL 5	029	45 5
RCL 4	030	45 4
−	031	30
SIN	032	23
f PSE (= SINβ)*	033	42 31
×	034	20
CHS	035	16
+	036	40
2	037	2
×	038	20
RCL 0	039	45 0
×	040	20
f π	041	42 16
÷	042	10
g RTN	043	43 32
OFF = ON		

* **Program will pause and show this value.**

To Run Program:

(which only runs one h at a time)
Turn on (Not in Program Mode)
Enter desired h,
then $\boxed{f}$ then A = $[x]^{1/2}$